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(*Recognosce notum, ignotum inspice*)

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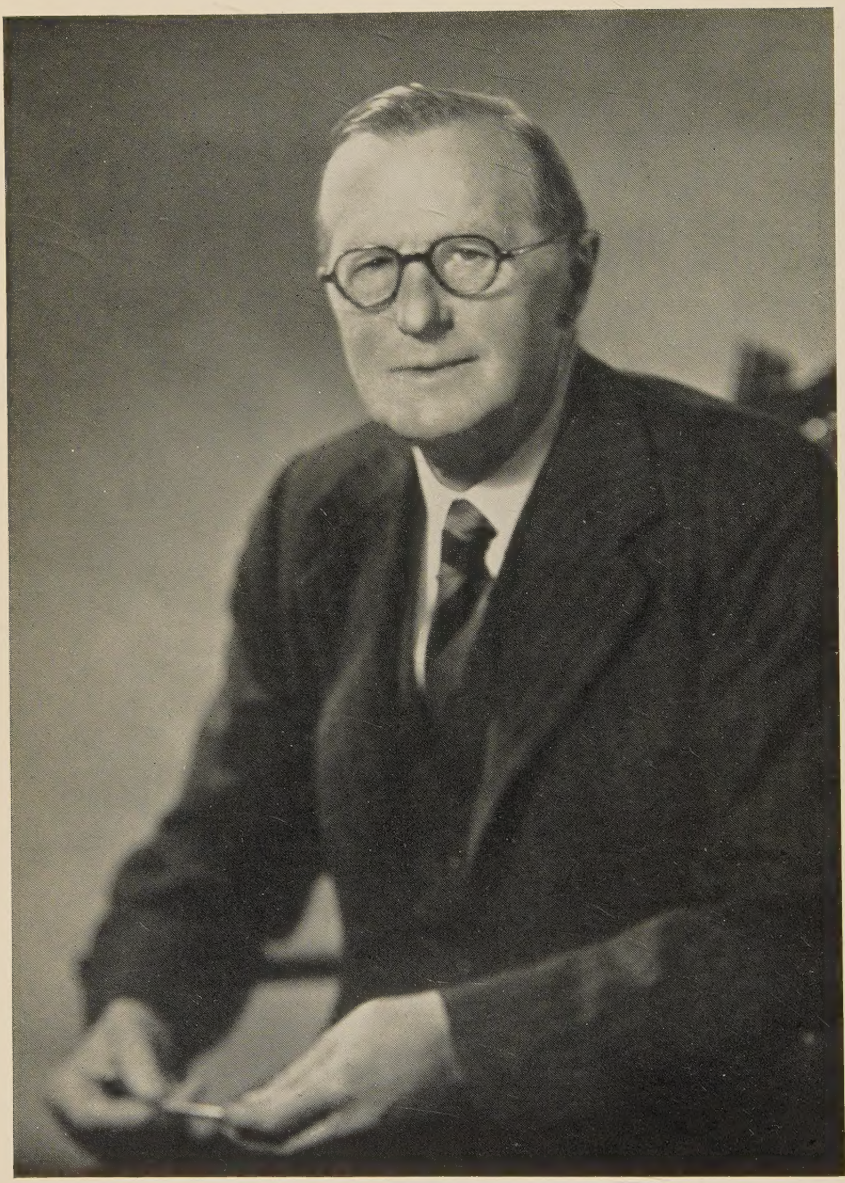

A. A. PEARSON
President, 1952

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PRESIDENTIAL ADDRESS

HOMMAGE AUX MYCOLOGUES FRANÇAIS

By A. A. PEARSON

Cette session est la première qui réunisse nos deux sociétés. De temps à autre nous nous rendons en Ecosse et en Irlande, mais jusqu'ici, la Société Britannique de Mycologie n'est pas sortie des Iles Britanniques. La société française s'est rendue en Algérie et en Espagne, mais jamais en Angleterre. En 1897, le mycologue Plowright l'avait invitée et elle avait accepté de venir, mais rien n'ayant été organisé, le projet fut abandonné. Quelques mycologues français éminents, notamment Quélet et Boudier, sont venus chez nous pendant une des sessions du Woolhope Naturalists' Club en 1897. Et René Maire s'est rendu à Baslow en 1909 pour la réunion du British Mycological Society, au cours de laquelle il a trouvé et nommé l'*Hygrophorus Reai* et le *Leptonia Reaae*. La première espèce a été retrouvée partout, mais la seconde doit être bien rare, et je ne me souviens pas qu'elle ait jamais été retrouvée. Par contre les Anglais sont venus fréquemment en France. Berkeley, Cooke et Phillips comptèrent parmi les membres fondateurs de la Société Mycologique de France. Notre ami Carleton Rea assistait naguère aux réunions de la société. Moi-même je suis membre depuis 1919 et vous pouvez comprendre combien je suis sensible à l'honneur que vous m'avez fait en m'élisant Président de la British Mycological Society pour une année qui réunit nos deux sociétés. Les présidents de notre Société Britannique ont une tâche qui leur est imposée: c'est de prononcer une allocution présidentielle qui doit être digne de l'occasion. C'est une bonne tradition et souvent elle a produit des discours de valeur, mais c'est un devoir auquel le président lui-même ne souscrit pas toujours avec bonne grâce. Le Président de la Société française est traité d'une façon moins exigeante. Pendant les sessions générales il est dispensé de l'obligation de présider et c'est un autre qui est choisi pour prendre sa place au cours de cette session. Il se retire de bonne grâce et peut-être avec un soupir de soulagement, bien content d'être dégagé de toute responsabilité.

Je n'ai, heureusement, éprouvé aucune difficulté à choisir le sujet de mon discours. Depuis le commencement du XIXème siècle, moment où la mycologie s'est élevée au rang des sciences sérieuses, ce sont les français qui se sont distingués, surtout dans leur étude systématique des champignons charnus: Basidiomycètes et Ascomycètes. Ce sont eux qui ont toujours marché en tête et les autres les ont suivis, quelquefois peut-être à contre cœur.

Je propose donc de faire de ce discours un hommage aux mycologues français.

Le plus ancien des livres sur les champignons qui ait été écrit par un français est celui de *Clusius*, dont le vrai nom est Charles de l'Escluse. Il naquit à Arras en 1526. Plus tard, il alla à Vienne (Autriche) et visita la

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Hongrie où il cueillit des plantes et des champignons qui forment la base de son ouvrage *Rariorum Plantarum Historia* (1601) dont trente-deux pages sont consacrées aux champignons. C'était le premier essai de classification des champignons qu'il a divisés en vingt-six genres. Mêlées au texte, il y a des gravures et aussi quelques planches en couleur exécutées par un artiste inconnu sous la direction de Clusius. Les planches ne sont pas d'un mérite extraordinaire mais montrent pour la première fois l'intérêt sérieux qu'un botaniste célèbre a accordé au sujet.

Près d'un siècle plus tard un autre botaniste renommé, *Joseph Pitton de Tournefort* (1694) fit un autre essai de classification. Dans ses *Elémens de Botanique*, il introduisit des cryptogames qu'il nommait 'des herbes dont on ne connaît ordinairement ni les fleurs ni les graines et qui se trouvent sur la terre'. Mais Tournefort consacrait seulement cinq pages aux champignons en ajoutant encore cinq pages de croquis en noir; bien peu de choses. Il donne une liste de 160 espèces qu'il divise en sept genres.

Sébastian Vaillant suivit en 1727 avec son *Botanicon Parisiense*. Il réussit même à faire illustrer son ouvrage de gravures de fleurs, de fougères, de mousses, de champignons, par le peintre du Roi; ces gravures sont en noir et n'ont guère de valeur pour l'histoire de la mycologie.

Le vrai fondateur de la mycologie française est *Bulliard* (1752–1793) qui en collaboration avec Ventenant écrivit et fit imprimer en quatre grands volumes son *Histoire des Champignons de France* qui contient 602 planches en couleur illustrant 467 espèces dont 160 étaient nouvelles. Son procédé de tirage était nouveau; et, de notre point de vue, peut-être pas très heureux. Les couleurs sont un peu trop ternes, mais l'ouvrage est néanmoins remarquable et embrasse toute la mycologie telle qu'elle était connue à cette époque. Bulliard avait déjà imprimé plusieurs grands tomes consacrés aux plantes à fleur, avec des croquis admirablement dessinés et colorés. Les champignons sont divisés en quatre ordres et vingt genres:

(1)	Semences, c.-à-d. spores enfermées à l'intérieur	10 genres
(2)	spores réparties sur tous les points de leur surface	2 genres
(3)	spores placées sur la partie supérieure	2 genres
(4)	spores placées sur la partie inférieure	6 genres

Toutes les espèces sont illustrées et beaucoup de détails sont dessinés, surtout ceux qui concernent les petits champignons, y compris les Myxomycètes. En parcourant ces livres volumineux l'étudiant pouvait s'émerveiller devant le grand monde des champignons. Il n'y trouvait pas une idée bien exacte du développement mystérieux qui s'effectue à l'intérieur des champignons car les basides, les asques et tous les détails relevés par la science moderne étaient encore inconnus. Bulliard a ses théories sur lesquelles il n'est pas besoin d'insister. Il esquisse une description de tout ce qu'il voit et fait une étude fascinante de la nouvelle science. Bulliard est mort à l'âge de 41 ans. La génération suivante était destinée à fouiller, avec un peu plus de succès, les organismes qu'il avait étudiés si intensément pendant sa courte vie. C'est *Joseph Henri Léveillé* (1796–1870) qui devait reconnaître la signification des basides et des cystides et leur donner les noms que nous employons aujourd'hui. On peut revendiquer pour Léveillé l'honneur d'être le premier à avoir séparé les champignons en deux catégories qu'il appela: *Basidiospori* et *Thecaspori*, et que nous nommons *Basidiomycètes* et *Ascomycètes*.

Je suis presque tenté de faire entrer *Persoon* (1761–1836) dans la galérie des mycologues français, car bien qu'il soit venu de l'Afrique du Sud, né de parents d'origine Hollandaise, il vécut à Paris de 1801 jusqu'à la fin de sa vie. Là il écrivit la plupart de ses livres et là il mourut, pauvre et délaissé. Le fruit mycologique était précieux, mais pour lui, il ne fut guère rafraîchissant.

Le nom le plus connu dans la mycologie systématique française est celui de *Lucien Quélet*, né en 1832 et mort en 1899. Il était médecin de campagne et portait un intérêt ardent à tous les aspects de l'histoire naturelle. Après avoir exercé la médecine pendant 20 ans, il se retire, surtout pour pouvoir se consacrer à l'étude des champignons. Il a écrit une série de mémoires descriptifs sur les espèces qu'il a cueillies dans le Jura et les Vosges qui ont été publiés dans divers bulletins. Sa *Flore Mycologique* parut en 1888. Ce livre qui traitait des hyménomycètes était fondé sur une classification qui diffère considérablement de celle d'Elias Fries, mycologue suédois, dont Quélet a été le disciple. Fries était mort depuis 10 ans mais sa méthode était universellement acceptée. Peu de mycologues français voulurent adopter les idées de Quélet. Après sa mort il y eut une tendance à les ignorer complètement, et, en 1900 et 1913, Bigeard et Guillemin publièrent deux volumes qui étaient pratiquement une nouvelle édition de Quélet réduite aux termes friesiens et reconnaissant à peine le grand rôle que Quélet avait joué dans le progrès de l'analyse systématique des champignons. Les maîtres, tels que Boudier, Patouillard, René Maire et Bataille approuvaient et nous aurions sans doute fait de même puisque *La Flore* était en avance sur son temps. Pendant ces dernières années, quelques-uns des nouveaux genres de Quélet ont été incorporés dans la classification moderne. *La Flore Mycologique* a fait époque. C'est un livre que nous devons fréquemment consulter surtout pour ses descriptions concises des espèces. Au moment où il parut, le microscope commençait à acquérir autant d'importance dans l'étude des champignons que les caractères macroscopiques. Quélet ne donne que la forme et la taille des spores. Il sait aussi qu'il existe des cystides et qu'elles peuvent avoir quelque importance diagnostique. Il dit lui-même que ce sont des 'organes délicats qui réservent encore plus d'une surprise aux investigations des mycologues'.

Le peu de cas que Quélet fit du microscope est un peu surprenant puisque l'instrument prenait déjà une place bien marquée dans la science mycologique. Les frères Tulasne venaient de mourir. *Louis René Tulasne* était un botaniste remarquable. Alors qu'il était assistant au Muséum d'Histoire Naturelle á Paris, il avait écrit une série de monographies sur quelques espèces à fleurs exotiques. En même temps il fit des découvertes frappantes sur la nature de plusieurs groupes de champignons. Son frère Charles fournissait des dessins qui sont très beaux. On se souvient de ces deux hommes surtout grâce à leurs trois grands volumes *Selecta Fungorum Carpologia* écrits en Latin et dont nous avons une belle traduction anglaise faite en 1931 par W. B. Grove. Ce livre traite de divers sujets, principalement des pyrenomycètes et contient des détails sur le pléomorphisme dans plusieurs espèces de champignons. Ce n'est là qu'une des contributions admirables que le microscope a rendu possibles. La plupart des mémoires de Tulasne ont paru dans les *Annales des Sciences Naturelles* et plusieurs sont ornés de gravures exécutées par son frère. Les observations sur les Tremelles qui parurent en 1853 eurent une grande influence sur la classification et Fries a reconnu sa dette à l'égard de Tulasne pour le nouvel ordre des Tremellinei qu'il a établi dans son *Hyménomycètes Europei.*

Un des contemporains de Quélet qui vécut, lui, jusqu'à un âge bien plus avancé est *Jean Louis Emile Boudier.* Il naquit en 1828 à Montmorency, non loin de Paris, où il s'établit comme pharmacien. Et ici je me permets d'indiquer le mérite extraordinaire que les pharmaciens français ont acquis comme mycologues. Il paraît qu'il y a, en France, une tradition dont je déplore l'absence en Angleterre, qui veut que les pharmaciens se consacrent à l'étude de quelques branches de l'histoire naturelle, en particulier la botanique. Un assez grand nombre d'entre eux sont attirés par la mycologie. Boudier fut un des meilleurs. Ses intérêts étaient variés; il s'occupait de presque tous les groupes, mais il a fait une étude intense et particulière des discomycètes. Il les a séparés en operculés et inoperculés et a établi une classification qui, bien que non universellement adoptée, n'en a pas moins exercé une grande influence. Les études précises de Boudier peuvent être appréciées au maximum grâce aux excellentes planches en couleur de son *Iconographie des champignons de France*, en quatre volumes dont l'un est consacré aux Hyménomycètes et deux autres aux Discomycètes. Boudier s'est imposé à la mémoire des français non seulement par ses livres puisqu'il n'a jamais publié une Flore complète des Discomycètes, mais aussi par ses activités sympathiques: il organisait chaque semaine des excursions dans les bois aux environs de Paris. Les jeunes étudiants qui avaient un tel cicerone, étaient bien privilégiés. Je n'ai pas eu la bonne fortune de connaître Boudier qui mourut en 1920, mais mon vieil ami Carleton Rea m'a souvent dit le plaisir qu'il éprouvait à botaniser avec un tel maître et le profit qu'il a tiré des réunions auxquelles il a assisté en France.

Un autre pharmacien qui lui aussi est devenu un des plus éminents des mycologues français est *Narcisse Patouillard* (1854–1926). Il naquit à Macornay dans le Jura mais il exerça sa profession à Paris. Patouillard a eu une bien grande influence sur la taxonomie des Hymenomycètes. En 1887 il publiait un petit livre intitulé *Les Hyménomycètes d'Europe* dans lequel il proposait une nouvelle classification basée sur une série d'observations microscopiques qu'il avait faites. L'ère du microscope était arrivée; avec elle les faits dont on pouvait se rendre compte grâce au fort grandissement, prirent une importance tout aussi grande que ceux que l'on pouvait voir â l'œil nu ou avec une lentille de poche. Son système fut élargi et perfectionné, 13 ans plus tard (1900), dans l'*Essai Taxonomique.* Ce petit livre traitait de toutes les familles connues des Hyménomycètes. Avec des modifications relativement faibles, la classification de Patouillard pour les Basidiomycètes a été adoptée par les mycologues modernes.

Un des hommes qui a tout fait pour glorifier la mycologie française est l'*Abbé Hubert Bourdot.* Né à Nièvre (Allier) en 1861, après une courte période d'enseignement dans une école, il fut nommé curé d'une petite ville de campagne, Saint-Priest-en-Murat (Allier) dans le centre de la France.

Il resta là jusqu'à sa mort en 1937. Il avait été nommé chanoine honoraire en 1928, ce qui ne changea nullement sa façon de vivre. Sans négliger les devoirs de son ministère, il trouvait le temps de s'occuper de botanique et il s'intéressait surtout aux champignons; d'abord aux agarics et aux bolets, ensuite aux autres groupes d'Hyménomycètes. En 1903 commençait sa collaboration avec *Amadée Galzin*, vétérinaire militaire qui, avec énergie et enthousiasme, ramassait des matériaux pour Bourdot. Ses activités auraient épuisé la patience de tout homme ordinaire. Après chaque expédition il apportait des centaines de spécimens. Bourdot m'écrivit, un jour, que Galzin avait trouvé des Tomentelles innombrables au milieu de débris dans un fossé profond et lui en avait envoyé plus de 700 exemplaires. Il ajouta: 'il m'avait déjà envoyé des milliers de ces plantes.' Elles continuaient toujours à lui arriver et dans une autre lettre il écrivit: 'Quand le bon Dieu eut créé les Corticiums, le diable, sans doûte, voulut faire quelque chose d'analogue et il créa les Tomentelles.'

Les Hyménomycètes de France de Bourdot et Galzin fut publié en 1928. C'est un des livres qui font époque. En tout, 1032 espèces, dont 150 nouvelles, y sont décrites. Ce sont les polypores de toutes sortes, ainsi que les Hydnes, les Corticinés, les Clavariés, les Tremellacées, etc., tout sauf les agarics et les bolets. Les resupinés sont traités d'une façon approfondie. Enfin nous avions un travail de base pour les différents genres d'Hétérobasidiées aussi bien que pour les genres intraitables comme les *Corticium*, *Peniophora*, *Tomentella*, *Poria* et bien d'autres. C'est un tour de force vraiment remarquable que d'avoir discipliné une telle masse de matériaux. Gilbert dans son excellent mémoire nous raconte que Bourdot était handicapé par une grande pauvreté. Heureusement que son vieux microscope était muni d'un bon objectif à sec et que lui-même était un véritable expert dans l'emploi de son attirail primitif. En vieillissant sa vue baissa tellement qu'il m'écrivit le 15 janvier 1934: 'J'ai été obligé de faire lire votre lettre; je ne distinguais pas la page écrite de la page blanche.' Cependant il arrivait toujours à employer son microscope même quand, pour lire ou écrire, il lui fallait mettre les yeux à 3 ou 4 centimètres de la page.

Nous arrivons maintenant à un mycologue dont l'influence sur les développements récents ne peut pas être exagérée. C'est notre regretté ami *René Maire*. Pendant sa vie on le nommait souvent: 'le maître de la mycologie contemporaine.' Ceux qui appartiennent à la jeune génération et qui ne l'ont connu qu'après la dernière guerre, au moment où la Société recommençait ses réunions annuelles, ne peuvent se faire une idée de sa maîtrise du sujet. Comme guide de nos expéditions, il était sans rival; il avait une mémoire prodigieuse des espèces. Et pourtant ce n'est que pendant sa jeunesse qu'il avait pu concentrer tous ses efforts sur les champignons. A partir de 1911, quand il fut nommé professeur à l'Université d'Alger il dut consacrer la plupart de son temps aux phanérogames et à l'assemblage de tous les matériaux requis pour sa *Flore de l'Afrique du Nord*, qui devait être son *magnum opus*; tâche immense. Il ne se contentait pas de transcrire les ouvrages des autres, il voulait recourir à l'expérience directe, ce qui nécessitait des voyages un peu partout pour cueillir et noter. Il lui fallait en même temps s'occuper de ses cours à l'Université. Il lui aurait fallu 5 ans de plus pour terminer ce travail monumental. Quand il mourut le 24 Novembre 1949, agé de 71 ans, cette grande œuvre qui comptait alors 8000 pages dactylographiées, était inachevée. Tandis qu'il s'occupait des plantes à fleurs, Maire n'oubliait pas les champignons vers lesquels il se tournait quelquefois comme pour se remémorer ses anciennes amours. Il aimait à assister aux réunions annuelles de la Société Mycologique de France auxquelles il présidait presque toujours. Aussi a-t-il fait quelques voyages d'un caractère purement mycologique, comme, par exemple, ses deux séjours en Catalogne pendant les automnes 1931 et 1933, au cours desquels il écrivit deux mémoires sur les espèces qu'il avait trouvées. Tôt dans sa carrière il s'était occupé de la cytologie des champignons. En 1901 il s'intéressa à l'évolution nucléale des rouilles et l'année suivante parurent ses *Recherches sur les Basidiomycètes*, qui traitent des problèmes de cytologie et de sexe. 'Les bases de la classification dans le genre *Russula*', qui se trouve dans le *Bulletin de la Société Mycologique de France* (1910), est le plus important de ses mémoires. Traduit en Anglais, ce mémoire est paru également dans nos *Transactions*, vol. III. L'effet de cet ouvrage ne tarda pas à se montrer dans le travail de divers auteurs sur les Russules. A cette époque, Maire eut des ennuis avec ses yeux et dut abandonner l'usage intense du microscope pour ne plus s'occuper que d'études taxinomiques. Mais il n'a jamais trouvé le temps de faire un travail d'ensemble sur les champignons. Nous n'avons pas de lui une 'Flore' qu'il était cependant en mesure d'écrire, grâce à toute sa documentation. Il ne faut pas oublier, malgré tout, que les six tomes de *Icones Selectae Fungorum* de Konrad et Maublanc n'auraient guère pu paraître sans lui. Les espèces critiques dessinées et décrites dans cet excellent ouvrage avaient été en grande partie déterminées par René Maire.

Mais je ne dispose que de peu de temps, et je me suis beaucoup étendu déjà, en parlant d'un seul de ces français remarquables dont nous célébrons, aujourd'hui, le rôle dans le développement de la mycologie. Comme tous ceux qui l'ont connu, je garderai de Maire un souvenir affectueux. Notre mémoire conservera toujours l'image de cet homme en jambières, marchant à grands pas dans les bois, se baissant de temps en temps pour examiner un champignon, ou s'asseyant parmi nous, ponctuant sa conversation d'anecdotes amusantes ou d'aphorismes classiques.

Nous ne devons pas oublier les nombreux mycologues qui ne publièrent pas suffisamment pour faire impression sur les générations futures mais dont la connaissance des espèces fut d'une très grande valeur pour leurs contemporains. Ce sont eux, surtout, qui ont conservé la tradition des espèces, ce qui a une importance particulière en mycologie. Je me souviens de plusieurs d'entre eux.

Paul Dumée fut au tout premier plan pendant plusieurs années et il a beaucoup aidé la Société Mycologique, surtout pendant la dure période de la guerre 1914–1918. Il a édité plusieurs livres populaires, notamment le 'Petit Atlas de Poche', dont les belles planches en couleur sont de Bessin.

Ernest René Peltereau (1842–1928) était notaire de profession, aussi pendant longtemps fut il trésorier de la Société. Il ne vint pas souvent parmi nous pendant sa vieillesse, mais quand il nous honorait de sa présence, nous étions tous empressés de profiter de sa grande expérience. Il était surtout grand connaisseur de Bolets.

Léon Joachim (1873–1945) est un autre de nos collègues français dont nous nous souvenons avec plaisir. Lui aussi était pharmacien et ses études sur les Cortinaires auraient dû prendre l'ampleur d'une monographie; mais il n'osait pas, car il connaissait trop bien ses lacunes. Sa modestie ne lui a permis de nous laisser que quelques notes insuffisantes.

Frédéric Bataille (1850–1946) a vécu jusqu'à l'âge de 96 ans. Il avait été maître d'école; cet homme aux talents variés était aussi un poète et un mycologue réputé. La mycologie a été le plus durable de ses enthousiasmes. C'était un fidèle disciple de Quélet en tout sauf en matière de classification. Sa connaissance des espèces était très vaste, mais il était si modeste que rarement il voulut décrire une espèce comme nouvelle, bien qu'il ait souvent dû en trouver. Les monographies, ou plutôt les clefs dichotomes de genres qu'il publiait de temps à autre, ont rendu de grands services. Plusieurs des groupes ou sections qu'il a introduits ont été adoptés par les auteurs modernes. Peu avant sa mort il acheva un ouvrage concernant les réactions chimiques sur la chair et la cuticle des champignons, en particulier des agarics. La Société Mycologique de France l'a publié séparément.

Je dois faire place ici, à un petit livre que nous avons bien connu dans le temps: c'est la *Nouvelle Flore des Champignons* de *Costantin* et *Dufour*. Ce livre embrassait dans une grande clef dichotome, toutes les espèces de Basidiomycètes et beaucoup d'Ascomycètes. Il y avait des petits croquis de chaque espèce: près de deux mille en tout, et même un code des couleurs: le tout pour six francs, avec reliure anglaise! Dieu seul sait ce que cela veut dire! Les clefs dichotomes sont à la mode, aujourd'hui, et nous en aurons sur une grande échelle. Mais nous soupirons quelquefois et regrettons les beaux jours de Costantin et Dufour.

En ce qui concerne la pathologie végétale, les français n'ont pas joué un rôle aussi prépondérant, mais on peut signaler quelques noms: *Mathieu Tillet*, petit fermier, a découvert, en 1750, la cause et le remède de la noircissure du blé. Il y a juste 70 ans, *Millardet* introduisait la bouille bordelaise dans le traitement préventif des maladies des plantes causées par les champignons. Il y en a d'autres, mais c'est dans l'étude des champignons nuisibles à l'homme que les français se sont distingués. Les dermatologues, les parasitologues et les vétérinaires ont été des mycologues d'une valeur supérieure à celle de leurs contemporains des autres pays. C'est à Paris qu'a commencé la mycologie médicale, grâce à l'initiative de l'Autrichien *David Gruby*; son exemple fut suivi plus tard par *E. Bodin* dans son livre: *Les Champignons parasites de l'homme* et par *Sabouraud*, auteur de l'ouvrage: *Les Teignes* (1910). Il y a aussi les éditions successives des livres sur la parasitologie de *Maurice Neveu-Lemaire* et d'*Emile Brumpt*. Le regretté *M. Langeron*, dont l'excellent livre *Précis de Mycologie* est très apprécié des anglais, a contribué largement à la mycologie médicale, par ses propres études.

N'oublions pas que le grand *Pasteur* (1821–1893), bien qu'il n'ait pas été en premier lieu un mycologue, s'est beaucoup occupé de certains champignons. C'est lui surtout qui nous a fourni de nouvelles méthodes pour étudier tout ce qui a trait à la mycologie industrielle. Il est venu trois fois chez nous; deux fois à Londres et une fois à Edimbourg. En septembre 1871, il visita nos grandes brasseries pour étudier les impuretés dans les levures employées dans le brassage des bières anglaises—les 'pale ales' et la 'porter'. Nos brasseurs furent sans doute, dûment émerveillés par la petite leçon de Pasteur qui leur démontrait l'intrusion clandestine de microbes importuns. Ils achetèrent même un microscope. A la fin de la visite, grâce à Dieu, nos bières généreuses restaient aussi bonnes qu'auparavant, mais, bien entendu, moins sujettes aux contretemps si fâcheux pour les consommateurs.

Tous ceux que j'ai nommés jusqu'ici appartiennent au passé: ce sont les disparus. Mais les mycologues d'aujourd'hui nous intéressent également. On ne peut pas les passer sous silence, même au risque de les faire rougir. Notre hommage aux mycologues de la France serait bien pauvre si l'on ne mentionnait pas la génération actuelle. Et, en effet, ils forment une véritable pléiade de talents.

Je commencerai par celui que je crois pouvoir appeler le doyen des mycologues français, le *Professeur A. Maublanc*. Pour avoir longtemps rempli la fonction de Secrétaire-général de la Société Mycologique de France il est assuré d'une bonne place dans l'histoire de la mycologie. Mais il y a d'autres raisons: ses études sur les maladies des plantes, son excellent livre *Les Champignons de France*, et surtout sa collaboration avec notre regretté ami *Paul Konrad*, l'excellent mycologue suisse. Ensemble ils ont produit les six tomes des *Icones Selectae Fungorum*. On doit ajouter aux fruits de cette collaboration l'ouvrage plus récent sur les Agaricales.

Un auteur de grande distinction est *Monsieur E. G. Gilbert*, l'aimable philosophe des mycologues français. Depuis 1919 des mémoires importants se trouvent dans le *Bulletin* mais c'est surtout par son grand ouvrage en trois tomes *Amanitaceae* que nous pouvons apprécier sa grande valeur. Nous consultons avec plaisir et profit ses livres sur la méthode à suivre dans la mycologie descriptive. Son petit livre sur les bolets nous a aidé à définer plus exactement beaucoup d'espèces critiques. En 1928 il a écrit, en coopération avec Kühner, un mémoire sur la réaction amyloïde des spores des différentes espèces d'*Amanita*. Parmi ses activités variées il a écrit des biographies de plusieurs grands systématistes français, qui illuminent bien le caractère et l'œuvre de ces mycologues.

En France, il y a deux centres d'activité mycologique: Paris et Lyon. Souvent ils s'entremêlent, mais il y a un nom qui se rattache d'une façon tellement intime à Lyon que l'on n'a qu'à mentionner l'un pour penser à l'autre. Comme vous le devinez, c'est *M. Marcel Josserand*. Tout récemment il nous a donné un dictionnaire des termes employés en mycologie. Ces termes n'ont pas toujours la même signification et on doit espérer que les interprétations de Josserand seront acceptées. Mais pour apprécier la valeur du mycologue lyonnais, il faut l'accompagner dans les bois ou feuilleter les pages des *Bulletins* de la Société Linnéene de Lyon et de la Société Mycologique de France, où l'on peut voir la façon avec laquelle il établit l'identité des espèces critiques. Nous avons tous admiré son mémoire sur l'ornementation des spores des Lactaires, étude bien délicate des caractères microscopiques.

Un autre mycologue lyonnais d'une génération plus jeune, *M. Marcel Locquin*, spécialiste des Lepiotes, a, lui aussi, fait des recherches sur la structure des spores des Russules. Bien que notre compatriote M. Richard Crawshay en 1930 ait fait des observations minutieuses des ornements des spores, leur étude approfondie, qui demande une grande aptitude dans le maniement du microscope, est une des tâches spéciales des mycologues français. *M. Georges Malençon* a aussi fait des contributions notables à ce sujet; son ouvrage remarquable sur les spores des Russules est bien connu. Je me rappelle Malençon, il y a trente ans, quand il était jeune homme, il étudiait alors les champignons en amateur et les mycologues parisiens le considéraient déjà comme un remarquable déterminateur. Quelques années après il se rangeait parmi les mycologues professionnels. Depuis 1932, il est attaché à l'Institut Scientifique Chérifien à Rabat, Maroc. Heureusement il ne se borne pas à l'étude des maladies des plantes et conserve l'enthousiasme de sa jeunesse pour la systématique des champignons charnus. Il a écrit des mémoires sur plusieurs aspects des champignons et ses vues portent si loin qu'on ne peut guère dire qu'il soit spécialiste d'aucun groupe. En Angleterre son petit livre sur les Truffes est très apprécié.

Aucun mycologue n'est plus respecté et plus admiré que le *Professeur Robert Kühner*. Il est également taxinomiste et cytologue expert. Son influence est visible dans tous les développements de taxinomie moderne. Ses deux monographies, *Le Genre Galera* et *Le Genre Mycena* sont dans la main de tous ceux qui font des études avancées des agarics et son travail sur bien d'autres genres fait également autorité.

Récemment il a coopéré avec *M. Henri Romagnési* pour écrire un livre sur les Agaricales. Personne ne pourrait être plus compétent pour produire un ouvrage de ce caractère. Nous l'avons attendu depuis longtemps et enfin il est sur le point de paraître. C'est le moment pour féliciter les auteurs. Romagnési est le plus jeune des deux, mais une intensité fièvreuse pour arriver au but lui a donné une connaissance des espèces égalée par peu de mycologues. Il s'est attaqué précisément à ces groupes que les autres ont évités comme la peste: les Rhodophylli, les Psathyrellae (ou faut-il dire Drosophilés?), les Flammules—et n'oublions pas les Russules; surtout les Russules! Sa contribution à l'étude de chacun de ces groupes est considérable et bien que nous-mêmes, d'envergure plus modeste et plutôt vieux jeu, nous déplorons quelquefois la trop grande division de la classification des genres et des espèces, nous devons reconnaître que cela devient inévitable pour tous ceux qui font une étude intense de n'importe quel groupe de champignons.

Un mycologue des plus accomplis, véritable virtuose, est le *Professeur Roger Heim*, directeur du Muséum d'Histoire Naturelle de Paris. Pendant les moments de liberté que lui laissent ses importants devoirs administratifs, il prend l'avion pour se rendre à l'autre bout du monde, où il ramasse assez de champignons pour donner à lui-même et à d'autres assez de travail pour le reste de leurs jours. Il a publié une remarquable monographie sur les Inocybes, nous a enchanté par une étude profonde de son nouveau genre *Termitomyces*, a mis en lumière les Russules tropicales, etc. Il écrit avec autorité sur tous les sujets qu'il aborde et c'est en même temps un orateur éloquent, que nous écoutons avec plaisir.

Nous savons tous comme il est difficile d'identifier un Cortinaire. Ce genre a été négligé par le passé, mais j'ai l'impression que nous allons sous peu rattraper le temps perdu. Le premier à avoir fait un vaillant effort pour jeter un peu de clarté sur le fourré épais des espèces des Cortinaires est le *Docteur Robert Henry.* Depuis près de vingt ans il nous donne des descriptions des Cortinaires dans le *Bulletin*, à mesure que se présente l'occasion de les étudier. Ses études de certains groupes sont très réussies, surtout celles de la section (ou du genre si vous voulez) *Phlegmacium*, et nous lui sommes reconnaissants d'avoir simplifié un peu leur détermination au moyen des clefs dichotomes qui nous permettent d'identifier les espèces qu'il a plus ou moins bien établies. Henry et d'autres qui le suivent croient être aidés par les réactifs chimiques colorants. Très bien! mais le seul moyen de bien connaître les Cortinaires, comme d'ailleurs tous les autres agarics, est de les étudier de telle façon que chaque espèce acquière, pour ainsi dire, une individualité. Il faut aussi de bonnes gravures en couleur et naturellement de bonnes descriptions, en un mot: les vieilles méthodes traditionnelles sont toujours nécessaires.

Il y a une autre série d'agarics que nous avons tranquillement laissée de côté: les Clitocybes hygrophanes. C'est *M. Georges Métrod* qui s'est fait le pionnier de ce groupe fastidieux. Comme il nous le dit, il reste encore un long chemin à courir avant de pouvoir dire que ces champignons banaux peuvent être déterminés avec certitude, mais M. Métrod a fait des progrès.

Il faut mettre fin à ces appréciations trop brèves, des mycologues vivants. Mais il faut auparavant mettre en scène une dame, *Madame Marcelle Le Gal*, dont la grâce égale la grande connaissance des champignons. Par ses études des Discomycètes elle se montre digne successeur de Boudier. Nous nous émerveillons de la patience infinie qui la rend capable de dessiner à main levée les ornements compliqués des spores. Nous la remercions d'avoir pris en main la rédaction et l'impression dans la *Revue de Mycologie* de la *Flore des Discomycètes* du Canon L. L. Grelet qui est mort en 1945. Une partie de cet ouvrage avait déjà été publiée dans le *Bulletin de la Société Botanique du Centre Ouest.* Nous espérons que cette Flore paraîtra dans un volume séparé. Revue par Madame Le Gal nous aurons enfin une Flore moderne des Discomycètes dont nous avons eu besoin depuis longtemps.

Au commencement du dix-neuvième siècle Persoon et Fries avaient fait de la mycologie une science sérieuse. Cependant les champignons ne présentaient qu'un intérêt secondaire pour les botanistes. Vers la fin du siècle, en Octobre 1884, la Société Mycologique de France fut fondée, société exclusivement consacrée à l'étude des champignons. Quélet fut le premier président. Pendant la première session générale qui eut lieu à Autun (Saône et Loire) les membres explorèrent les bois des environs. Ce n'était pas la première fois que les mycologues se rencontraient pour ramasser des champignons. C'est en Angleterre que le Club des Naturalistes de Woolhope à Hereford avait commencé les *Fungus Forays* (Raids des Champignons), nom un peu bizarre pour des réunions de mycologues dont le but est de cueillir et de déterminer des champignons. Ernest Roze avait organisé la première excursion française en 1876. Un des objets de la nouvelle société était de combiner ces recherches en plein air avec les réunions des membres pour les discussions des affaires de la Société. On décida que la Société aurait son propre journal et le Bulletin commença sa carrière distinguée en 1885. Avant cela les mycologues s'adressaient ailleurs pour la publication de leurs mémoires. Cependant il existait un autre périodique, *La Revue Mycologique*. Celle-ci avait été fondée en 1879. Pendant 22 ans elle concurrença le nouveau Bulletin. Son propriétaire, le Commandant C. Rouméguère, en fut le premier éditeur; son gendre, le docteur René Ferry, le suivit. *La Revue Mycologique* avait été assez utile, ses lecteurs ayant été tenus au courant des activités mycologiques mondiales. Dans le *Bulletin* de la Société, il y avait plus de sujets originaux, bien que Quélet lui-même n'y contribuât pas, s'étant brouillé avec la direction. (Les querelles de mycologues ne sont pas inconnues depuis!) Le premier Secrétaire de la Société fut le Docteur A. Mougeot. Après lui, il y en eut d'autres. En 1908, un jeune homme, M. Maublanc, fut élu secrétaire et éditeur du *Bulletin*. Sauf entre 1913 et 1919, il a rempli ces fonctions sans interruption et il les remplit encore; il n'est pas si jeune, ni peut-être tout aussi actif, mais il est toujours à la hauteur de sa tâche. Depuis 1884, le *Bulletin de la Société mycologique de France* a été le centre des activités mycologiques. Des mémoires sur les champignons pathogènes s'y trouvent de temps à autres, mais pour la plupart ce sont les problèmes de taxinomie qui remplissent ses pages. Les Basidiomycètes occupent plus de place que les autres champignons, surtout, dernièrement, les agarics. On y trouve souvent des planches en couleur. Il y en eut dès les premières années. Dans le tome III (1887), Boudier ainsi que Rolland en avaient insérées plusieurs. Dans les années récentes nous avons vu avec plaisir que les bons mycologues sont capables de manier le pinceau avec un vrai talent. Le tome XLI (1925) est important à ce point de vue. C'est dans ce volume qu'a commencé à paraître, sous le nom d'*Atlas*, une série d'illustrations. La planche No. 1 était de Patouillard et la planche No. 2, de Malençon. Ainsi la génération des vieux et celle des jeunes commençaient une série qui continue toujours. La dernière planche de l'*Atlas* était dans le tome LXVI, et avait le numéro 96. Nous espérons que malgré les frais de tirage en couleur qui ne cessent d'augmenter, la série pourra continuer. Plus tôt, de 1906 à 1910, la Société avait distribué un autre 'Atlas': 120 planches en couleur, illustrant 283 espèces de champignons. Elles ont été reliées plus tard et présentées avec un texte de Rolland, bon mycologue et très actif pendant les premières années d'existence de la Société. Toutes les belles aquarelles étaient de A. Bessin, dessinateur professionnel.

Depuis 1936, une autre publication périodique s'occupe exclusivement de champignons: la *Revue de Mycologie*. Elle est associée au Muséum d'Histoire Naturelle à Paris. Son éditeur et inspirateur est le Professeur Roger Heim. Son programme est assez varié. Elle s'occupe souvent des espèces non européennes. On y trouve aussi des suppléments, rédigés dans un style moins sérieuse, et qui contiennent souvent des essais humoristiques de notre ami M. Georges Becker. Les mycophages ne sont pas négligés, et l'*Essai de Mycogastronomie* par le Docteur Paul Ramain doit être le meilleur dans son genre. Il y a aussi un Supplément Colonial édité par M. Claude Moreau qui s'occupe surtout des maladies des plantes dans les colonies françaises. Il faut mentionner la belle série des mémoires de divers auteurs, publiés séparément par le Muséum National, qui traitent des collections faites par M. Heim à Madagascar.

Il existe en outre des bulletins provinciaux qui réservent une place aux champignons. J'ai déjà indiqué l'importance de la section mycologique du *Bulletin de la Société Linnéenne de Lyon.* D'autres sociétés d'histoire naturelle font de même. M. Piane, pendant les six dernières années, a édité une fois par an, un bulletin excellent pour la Société des Naturalistes d'Oyonnax, dans lequel domine la mycologie. D'autres sociétés se sont associées pour produire un bulletin trimestriel comprenant parfois des articles sur les champignons. Il existe aussi une vingtaine de petites sociétés mycologiques en province.

Un autre aspect des études mycologiques est l'empoisonnement par les champignons. Là encore nos collègues français sont en avance. Il suffit d'indiquer la part prééminente prise par le président actuel de la Société Mycologique de France, M. Dujarric de la Rivière, de l'Institut Pasteur, dans la découverte du sérum anti-phalloidien. En Angleterre, l'aspect médical des empoisonnements fongiques a été négligé, pour la raison bien simple que ceux-ci sont rares, les seuls champignons que l'on mange couramment étant l'*Agaricus campestris* et le champignon de couche.

Je viens de passer en revue, bien brièvement, les diverses activités des mycologues français, et j'ai tâché d'exprimer notre appréciation de leur travail. J'ai parlé du passé et du présent. Que peut-on dire de l'avenir? Des réunions comme celle-ci sont des occasions sociales et nous sommes contents de revoir nos amis qui viennent de différents pays. Ces 'meetings' encouragent des sentiments de camaraderie que ne gâtent pas les préjugés nationaux. Une grande réunion comme la nôtre montre que notre science devient presque populaire. Une grande proportion des membres de nos deux sociétés sont des amateurs. Pourrons-nous retenir leur intérêt? Les champignons ont un attrait étrange qui résistera aux complexités introduites au cours des années récentes. Ceux qui s'occupent de leur étude ne sont pas tous capables de faire usage du microscope comme il le faut aujourd'hui; mais la classification établie par Elias Fries ne nous satisfait plus. Il y a sans doute une fausse simplification dans le système friesien qui a cependant duré plus d'un siècle. Les nouveaux systèmes seront, peut-être, plus proches de ce qu'il nous plaît de nommer un système naturel. Il faut qu'il soit à la portée de tous et non seulement des élus. Bien sûr, le microscope est essentiel et en général on peut dire que les déterminations spécifiques sont un peu moins difficiles qu'avant, et plus précises. Il est vrai que les anciens firent des merveilles sans le microscope. Les Fries et les Quélet possédaient un flair sans lequel un mycologue, même aujourd'hui, a peu de chances de succès. Pour les espèces critiques il faut reconnaître que la précision est à peine possible quand on ne connaît pas les caractères microscopiques, mais pour cela il ne faut pas une expertise hors de la portée des gens ordinaires. Nous serons souvent, bien sûr, déçus dans nos efforts pour arriver au nom exact. N'est-ce-pas là un des charmes de notre étude? Si elle était trop facile, nous perdrions peut-être l'intérêt que nous y portons.

Je termine en félicitant nos confrères français de tout ce qu'ils ont fait pour le progrès de la mycologie.

STUDIES ON PLANKTON PARASITES

II. THE PARASITISM OF DIATOMS WITH SPECIAL REFERENCE TO LAKES IN THE ENGLISH LAKE DISTRICT

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(With 6 Text-figures)

In a survey of the incidence of parasitism of plankton diatoms by chytridiaceous fungi in the English Lake District particular attention has been paid to the occurrence of fungi on *Asterionella formosa* and *Fragilaria crotonensis*, and to the effect of parasitism on their seasonal distribution. Almost all the plankton diatoms are infected by fungi, some of which are described, including: *Rhizophidium planktonicum*, *Chytriomyces* sp., *Zygorhizidium planktonicum* Canter, n.sp., and *Septosperma anomala* on *Asterionella formosa*; *Zygorhizidium melosirae*, *Septosperma* sp., and ? *Rhizophidium fusus* on *Melosira italica*; and *Chytridium versatile* on *Tabellaria*. Some of the parasites cannot be named until further details of their life history are known. Parasites of plankton diatoms are also recorded from other bodies of water in Great Britain and various parts of Europe. Fluorescence microscopy has been used to follow the effects of parasitism on the host cells. The occurrence of bacteria on two of the fungi is discussed.

INTRODUCTION

In the first and third papers (Canter & Lund, 1948, 1951) in this series we have considered various aspects of the parasitism of *Asterionella formosa* Hass. by *Rhizophidium planktonicum* Canter. The present account covers the plankton diatoms in the English Lake District as a whole. Through the kindness of those mentioned on pp. 35–36 it has been possible to make some observations on the parasitism of plankton diatoms in other parts of Europe and New Zealand. Samples sent from some areas of Europe, Africa and Australia either contained no diatoms or no parasites.

It is often a considerable time before all the diagnostic features in the life history of a chytridiaceous fungus are known. They may not all occur during a single period of infection of the host, the diatom may be rare and there is often difficulty in observing the life history in preserved material. Nevertheless, we have included figures and such descriptions as are possible of some of these fungi in the hope that others may observe the missing stages and be aware that the fungi concerned occur elsewhere.

For each algal species or genus the parasites observed are first named or described, after which follows a list of the lakes in which they occur.

The methods of collection and estimation of the host and parasite populations described in our previous papers (Canter & Lund, 1948; Lund, 1950) are only summarized here.

The plankton of three lakes in the English Lake District, Windermere, Esthwaite Water and Blelham Tarn has been examined almost every week for 7 years (Lund, 1949, 1950), and fungal parasitism has received detailed attention for 5½ years. Other lakes in the area have been sampled monthly for the last 3 years.

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* Mrs J. W. G. Lund, whose thanks are due to the Central Research Fund of the University of London for a grant for the purchase of a microscope.

Collections in Windermere, Esthwaite Water and Blelham Tarn were made at fixed buoys in the areas of deepest water. Elsewhere, water samples were usually obtained from an exposed part of the shore by throwing out a sample bottle and by towing a net from the same position. Occasionally, samples were taken after rowing into an area of deep water. That the method of collecting from the shore gave a true picture of the plankton populations in the surface waters seems probable both from the usual paucity of littoral non-planktonic algae and from comparison with those samples collected by boat. Sometimes in stormy weather littoral algae were common in the samples.

The algal numbers were estimated by sedimentation of a suitable volume of water and counting on an inverted microscope. The mean number of cells per colony of *Fragilaria crotonensis* (Edw.) Kitton and *Melosira italica* (Ehr.) Kütz. was estimated by counting the number of live cells in 20, 50 or 100 colonies. In the earlier years of the period under review the cells in 50 or 100 colonies were counted, but this was extremely time-consuming, and in the last 2 years only 20 colonies were counted. This modification is suitable for showing the major changes in the density of the population.

Fungal infection was recorded by Canter & Lund (1948) as the percentage of diatom cells bearing viable parasite cells (i.e. encysted zoospores or undehisced sporangia). In the following tables, as in Canter & Lund (1951), the percentage of diatoms bearing empty sporangia is also included. The former is called the percentage of the population bearing *infective* cells and the latter that bearing *infected* cells. In *Fragilaria crotonensis* only the latter method is generally practicable since so large a number of parasites often occur on one cell that it is impossible to carry out the more detailed separation into zoospores, sporangia and empty sporangia. This explains the very high percentage of infection commonly recorded at the end of an epidemic when most of the diatom cells bear empty sporangia. The method does, however, give a correct picture of the severity of an epidemic. The few detailed analyses made of the development of fungal epidemics on other diatoms showed the same cycle as that of *Rhizophidium planktonicum* on *Asterionella formosa*.

PARASITES OF *ASTERIONELLA FORMOSA* HASS.

Species 1. Rhizophidium planktonicum *Canter*

(Fig. 1 A, B)

Further observations have shown that the sporangia associated with the sexually formed resting spores described for this species are spherical, dehisce apically, and owing to the thin wall soon collapse (Canter & Lund, 1948, fig. 11 I). Very frequently no empty sporangium can be found, and it is possible that sometimes the wall disappears either at or soon after dehiscence. Populations of *Asterionella* containing sporangia and sexually formed spores of this species (Fig. 1 A, B) have been observed in Windermere, Esthwaite Water, Blelham Tarn, Lowes Water, Crummock Water, Ullswater, Bassenthwaite, Hawes Water and Loughrigg Tarn in the English Lake District, and in Loch Uanagan in Scotland.

The laterally dehiscing sporangia (Canter & Lund, 1948, fig. 10B) belong to the next species.

Species 2. Chytriomyces *sp.* (Fig. 1 C, D)

The sporangium of this fungus is spherical and resembles that of *Rhizophidium planktonicum.* Dehiscence has not been observed, but it is possible that it is operculate. There is a wide lateral (very rarely apical) opening, and occasionally in preserved material what may be a lid has been found attached to empty sporangia. The sporangium wall is more robust than that of *R. planktonicum* and the empty sporangium retains its shape. The rhizoidal system only differs from that of *R. planktonicum* in being more robust. The resting spore is spherical, asexually formed and contains several refractive globules. In the Lake District material (Blelham Tarn, Windermere) the resting spore (4·5–8 μ in diameter) often has one or more refractive thickened areas developed on its outer surface (Fig. 1 C). These could not be seen in the material from Malham Tarn, October 1951, or Loch Lochy, 1951 (Fig. 1 D), the only other localities where resting spores occurred.

Sporangia similar to the above have been seen in Bassenthwaite and Sunbiggin Tarn, also in preserved material from Loch Erne, Erken and Lake Clearwater.

Species 3. Zygorhizidium planktonicum *Canter* (p. 34) (Fig. 1 E–M)

This species is characterized by its obpyriform sporangium 3·8–9 μ high and 2·9–8 μ broad, and a short, branched rhizoidal system (Fig. 1 F). The sporangium contains up to twenty zoospores, each with a single refractive globule. The resting spore, 6–8·5 μ high × 4·9–6·7 μ broad, is sexually formed (Fig. 1 I, K–M). The male thallus, 2·5–4 μ, makes contact with the female via a conjugation tube up to 12 μ long. The male and female thalli may be situated on the same or adjacent host cells. The male thallus appears to have a small rhizoidal system and to be larger than the encysted zoospore (Fig. 1 E, I). Most of the information about this fungus has been obtained from preserved material. Only once has it been observed in the living state when the content of the resting spore consisted of numerous globules (Fig. 1 M).

Sporangia of this type, together with resting spores, have been seen in Malham Tarn, Lough Derg, Lough Talt, Sarnersee and Lago Como; sporangia only in Lough Oughter, Loch Tay and Bielersee. It is believed that this fungus can be identified with *Zygorhizidium planktonicum* (p. 34) on *Synedra acus* var. *angustissima.* Although no operculum has been found in the specimens occurring on *Asterionella*, the resemblance between the two fungi is so striking that they are regarded as identical.

Species 4 (Fig. 1 N)

This is possibly the same as the fungus on *Fragilaria* and *Tabellaria* (pp. 20, 27), identified as *Chytridium versatile* Scherffel, but dehiscence of the

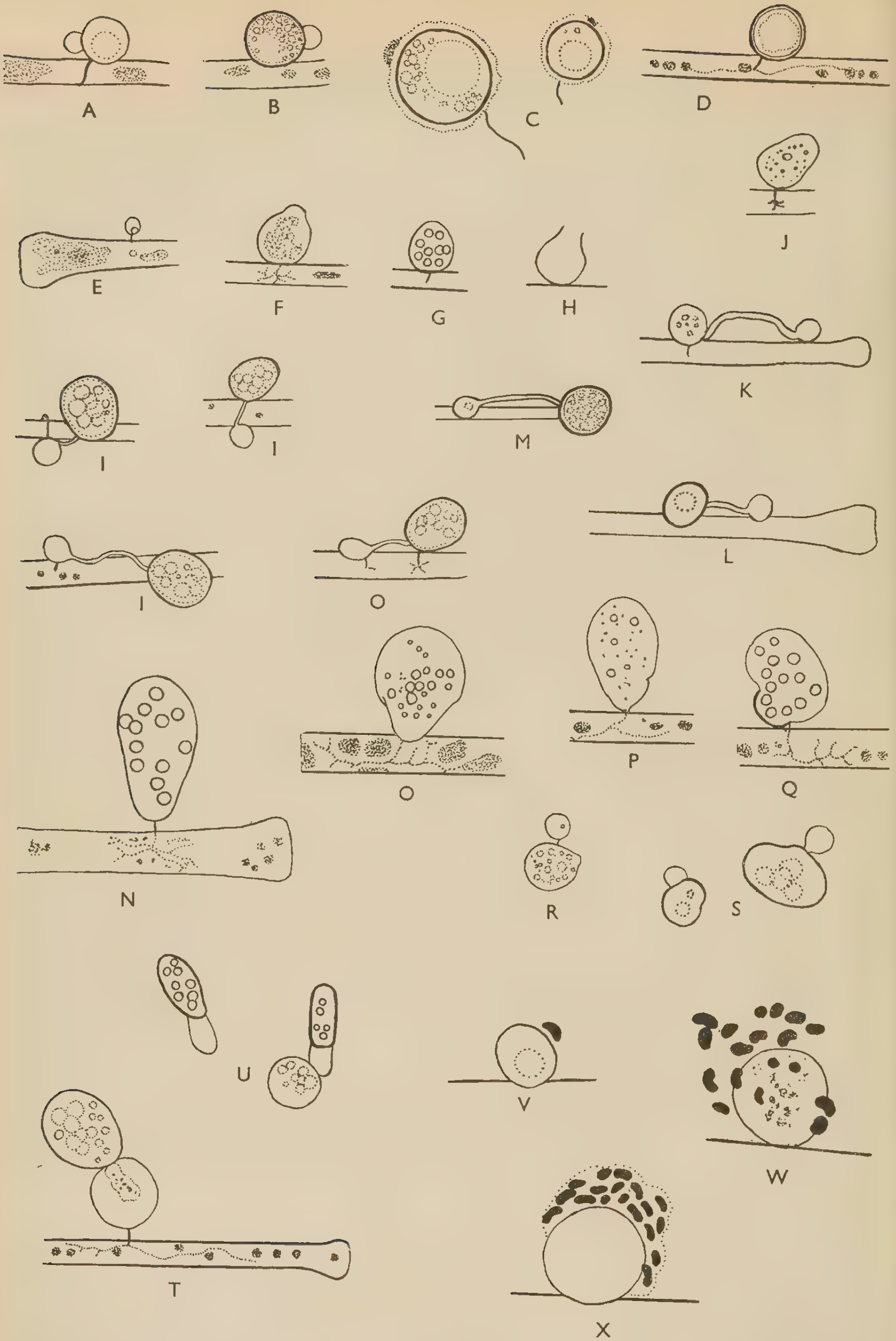

Fig. 1. Chytrids parasitizing *Asterionella formosa* Hass. A, B, sexually formed resting spores of *Rhizophidium planktonicum* Canter: A, young; B, mature. C, D, asexual resting spores of species originally included in *R. planktonicum*; C, from Blelham Tarn; D, from Loch Lochy. E–M, *Zygorhizidium planktonicum* n.sp. E–I, from Loch Talt: E, encysted zoospore; F, young sporangium with rhizoidal system; G, mature and H, empty sporangium; I, resting spores. J, K, from Loch Derg; J, young sporangium; K, immature resting spore. L, M, resting spores: L, from Sarnersee; M, from Malham Tarn. N, species 4, from the tarn at Tarn. O–S, 'Species 5' from the tarn at Tarn: O, P, immature sporangia, Q, mature sporangium; R, young resting spore; S, mature resting spores. T, U, *Septosperma anomala* (Couch) Whiffen: T, sporangium; U, resting spores (on *Chytriomyces* from Sunbiggin Tarn). V–X, bacteria on *Rhizophidium planktonicum*: V, W, living; V, an encysted zoospore; W, an immature sporangium; X, dried and stained in alkaline aqueous gentian violet in aniline water. C, N, O–Q, ×1670; R, S, ×1340; K ×970; the rest ×1066.

sporangium has not been observed. It occurs in the same tarn as the next species.

Species 5 (Fig. 1 O–S)

This species has been found only in the shallow tarn at Tarns, near Silloth, Cumberland, the only body of water examined in the present survey which has deeply peat-stained water. The *Asterionella* colonies are sometimes composed of over one hundred cells. After the encysted zoospore has enlarged slightly, further growth of the young sporangium is unilateral and the little expanded portion thickens to form a hemispherical protuberance on the side of the sporangium (Fig. 1 Q). Sporangia vary from obovoid to irregular in shape and are 7·5–9·0μ high and 3·5–5·0μ diameter at the apex of the thickened portion. Dehiscence has not been seen, but it would seem that the zoospores have a conspicuous refractive globule. The single rhizoid usually bifurcates near its point of entry into the cell (Fig. 1 O–Q), the two threads extending some distance in opposite directions with the production of short lateral branches. Resting spores are sexually formed (Fig. 1 R, S) and of irregular shape varying from 4·5 by 4μ to 8 by 6μ; the wall is smooth and one or more globules occur within according to the size of the spore. The empty adherent male cell is 2–2·5μ diameter.

Septosperma anomalum (*Couch*) *Whiffen* (Fig. 1 T, U)

This chytrid has once been found infecting a fungus on *Asterionella*. It occurred on sporangia which probably belong to 'species 2' from Sunbiggin Tarn (October 1951).

Parasitism of *Asterionella* is widespread, and fungi have been observed in the following lakes although not in sufficient quantity to permit identification: Derwentwater, Thirlmere, Elterwater, Grasmere, Bigland Tarn, Middlerigg Tarn, Loch Cullin, Loughs Erne and Glencar, Lago Maggiore, Como, Lugano, Mergazzo, Lac Léman, Baldeggersee, Zürcher Obersee, Tuusulanjarvi, Swithland Reservoir, Loosdrechtsee Plassen, Overwater and Bielersee.

Infection reaching epidemic proportions (25 % or more of the host cells infected) has frequently been observed (Tables 1 and 2). Certain general features of epidemics can be gleaned from Table 2 and are only summarized here since they are discussed in detail in Canter and Lund (1948, 1951). The figures given in it do not necessarily show the full extent of the reduction in the numbers of *Asterionella* or in the number of live cells per colony. Epidemics are most frequent in the most eutrophic lake, Esthwaite Water, which also had the two longest epidemics recorded (February–April 1949; January–April 1950) and in each case, after a gap of a month or two, these were followed by shorter and more severe epidemics. In each of these years the *Asterionella* maximum was very much less than usual (Canter & Lund, 1951; Lund, 1950). Epidemics are least frequent in the north basin of Windermere. This is the most oligotrophic of the four bodies of water, but almost every year the spring plankton is predominantly composed of *Asterionella* (often over 90 % of the phytoplankton), while the maxima themselves are generally large (Lund, 1950; fig. 7; 10^7 cells/l. in 1951).

The changes in the density of the population (Table 2, cols. 4–6) reflect both the effects of parasitism and other factors (see Lund, 1950). Thus, in late winter or spring, the close of an epidemic is usually followed by a rapid increase in diatom numbers, conditions being favourable for active growth, whereas in mid-winter light may be insufficient for growth and in late spring or early summer the water may be depleted of available silica, in such cases the population remains static or decreases after an epidemic is over. The changes in the numbers of *Asterionella* in Esthwaite Water in early 1949 and 1950 may seem small in view of the prolonged epidemics, but in their absence there normally occurs a rise in population to between 5000 and 10,000 cells/ml.

Table 1. *Incidence of epidemics of* Rhizophidium planktonicum *agg.* (*see pp.* 14–15) *on* Asterionella formosa *Hass. in lakes other than those in Table* 2

Lake	Max. inf.	Date
Derwentwater	42	13 Jan.–11 Feb. 1949
Derwentwater	38	10–18 Oct. 1950
Bassenthwaite	49	11–18 Oct. 1950
Bassenthwaite	74	27 Feb.–22 Mar. 1951
Loweswater	36	12 Apr. 1947
Loweswater	76	7 Mar.–4 Apr. 1949
Loweswater	52	11–24 Jan. 1950
Loweswater	42	1–18 Oct. 1950
Loweswater	41	7 Nov. 1951
Ullswater	49	28 Apr. 1949
Ullswater	30	6 Mar. 1951
Haweswater	29	3 Feb. 1949
Middlerigg Tarn	34	2 Jan. 1951
Loughrigg Tarn	43	8–27 Mar. 1949
Malham Tarn	35	13 Oct. 1951
Sarnersee	±25	24 July 1948
Zürcher Obersee	79	2 July 1948
Lake Clearwater	61	11 Apr. 1943

(*Max. inf.*, maximum percentage of the *Asterionella* population infected. The dates cover the period during which epidemics occurred, most consecutive collections were made fortnightly.)

The number of live cells per colony of *Asterionella* falls during the course of an epidemic (Table 2, cols. 7–9) and rises afterwards. This is more clearly seen in the figures in Canter and Lund (1948, 1951), only the fall or early stages of recovery appearing in Table 2.

The statement that epidemics are generally absent in spring (Canter & Lund, 1948) is not borne out by the observations of the last 3 years. It now appears that epidemics occur at any time when the *Asterionella* population is 10 or more cells/ml., nor is it certain that epidemics do not occur at lesser densities. Between 10 and 10,000 cells/ml., the density of the population does not appear to affect the chances of an epidemic occurring. Indeed, more epidemics have occurred at relatively low than at relatively high densities of *Asterionella*. This is to be expected if the incidence of epidemics is governed by another factor or factors, for it is only for relatively short periods of the year that *Asterionella* is present in large numbers (e.g. over 500 cells/ml.). What this other factor is cannot be suggested yet, though it would appear to be chemical rather than physical in nature. A comparison of the dates of the epidemics in Table 2 hows that those in Windermere usually differ from those of Blelham Tarn nd Esthwaite Water. Only one epidemic out of fifteen occurring in Esthwaite Water and Windermere south basin occurs in the same period;

Table 2. *Incidence of epidemics of* Rhizophidium planktonicum *agg.* (*see pp.* 14–15) *on* Asterionella formosa *Hass.* (25% *or more host cells bearing parasites*) *between* 1945 *and autumn* 1951 *inclusive in Windermere, Blelham Tarn and Esthwaite Water*

			Asterionella					
	Rhizophidium		Cells per ml.			Cells per col.		
Year	Epid. period	Max. inf.	Before	Max. inf.	After	Before	Max. inf.	After
Windermere, north basin								
1948	8 Sept.–4 Oct.	63	115	38	5	6·2	4·8	5·1
1949	14 Feb.–7 Mar.	27	17	24	29	6·7	5·4	4·8
1949	7 Mar.–4 Apr.	34	29	45	136	4·8	4·5	4·9
1950	16–25 Oct.	26	83	216	292	6·9	6·8	6·5
1951	24 Sept.–15 Oct.	48	99	35	21	7·0	4·2	4·6
Windermere, south basin								
1945	17 Oct.–5 Dec.	> 50	415	37	17	6·7	5·2	4·8
1948	22 June–14 July	29	79	319	295	9·9	5·2	4·6
1948	8 Sept.–1 Oct.	91	164	12	6	7·1	1·8	5·6
1949	23 Feb.–11 Apr.	35	100	137	342	5·6	3·4	5·7
1949	11 Oct.–4 Dec.	48	48	21	20	9·5	5·3	6·8
1951	28 Sept.–8 Oct.	44	325	217	234	4·9	3·8	3·4
Blelham Tarn								
1946	1–29 Jan.	31	207	197	68	6·7	5·8	4·0
1946	10–17 Sept.	42	39	17	9	4·6	3·4	4·5
1947	20 Mar.–8 Apr.	29	71	22	78	5·1	5·4	6·1
1948	15–26 Mar.	25	948	919	1104	3·7	3·3	2·8
1948	14–28 May	38	944	253	20	8·6	5·2	4·8
1949	16 Apr.–5 May	50	2767	1848	34	3·7	2·4	3·1
1950	25 Sept.–9 Oct.	48	25	25	18	6·9	3·6	3·8
1951	9–23 Apr.	32	295	1014	682	4·7	5·2	3·0
Esthwaite Water								
1946	31 Oct.–18 Nov.	30	322	267	785	7·5	5·9	4·9
1947	1–20 Jan.	45	86	54	43	7·1	4·9	6·1
1947	22 Apr.–2 May	25	11952	5946	6490	4·7	4·7	5·0
1947	23–31 Oct.	51	101	54	83	8·3	6·3	4·1
1949	15–21 Feb.	30	102	164	140	5·9	4·7	4·4
1949	23 Feb.–5 Apr.	54	140	88	29	4·4	3·1	3·2
1949	16 May–3 June	68	104	167	< 1	7·4	4·3	4·1
1950	1 Jan.–11 Apr.	50	24	32	58	6·1	4·4	3·9
1950	12–26 June	72	45	7	4	5·8	3·4	7·7
1950	30 Oct.–27 Nov.	68	107	21	4	6·2	2·9	4·3
1951	15 Oct.–22 Oct.	80	167	15	8	6·7	1·1	5·7

(*Epid. period*, dates between start and end of an epidemic; *max. inf.*, highest percentage of ells in the *Asterionella* population bearing parasites; *cells per ml.* of *Asterionella* at the time of ampling *before* the start of the epidemic; *max. inf.*, at the time of maximum infection, *after*, at he first time of sampling after the epidemic, and *cells per col.*, the average number of live *Aster-nella* cells in a colony on the same dates. Samples *before* and *after* an epidemic usually taken within a week of its start or end.)

et cells and parasites pass from Esthwaite Water during periods when pidemics occur into Windermere. The same applies to Blelham Tarn nd Windermere north basin, and the two basins of Windermere itself. The physical conditions (temperature, illumination and water movements) n the four bodies of water generally show changes over the year which only differ in detail. Parasitism can occur under all known physical and chemical conditions, and in these and other lakes some parasitism nearly always occurs when *Asterionella* cells can be observed.

PARASITES OF *FRAGILARIA CROTONENSIS* (Edw.) Kitton

Species 1 *and* 2 (Fig. 2A–E)

In the English Lake District this diatom is infected by *Rhizophidium fragilariae* Canter (1950) and *Chytridium versatile* Scherffel. Although the fungi often occur in abundance, resting spores of neither have been seen. Their method of existence from season to season remains a mystery. *Rhizophidium fragilariae* (Fig. 2A) causes the major decreases in diatom numbers and occurs for much longer periods than *Chytridium versatile* (Fig. 2B–E), and it may be that it perennates throughout the year in the sporangial stage though the numbers are at times too small to be observed in ordinary routine observations. *C. versatile* is known to infect other planktonic, epiphytic and unattached littoral diatoms and it may therefore persist on other species. Table 3 records epidemics in various lakes in the district. The severity of the epidemics is often so great that superparasitism (DeBach & Smith, 1947) probably occurs.

Species 3 (Fig. 2F–O)

Another species, about which little is known at present, parasitizes *Fragilaria crotonensis* in other parts of Great Britain and Europe (Table 4). A similar parasite occurs in Rostherne Mere, Barn Elms and Swithland reservoirs. The empty sporangia have a wide pore, and the apical part of the wall may be recurved. The fungus attaches itself by an extra-matrical germ tube. Neither dehiscence of the sporangium nor the occurrence of resting spores has been observed. This may be the same as the fungus observed in samples from Lago Lugano or Lago Maggiore collected in 1946–7. In view of the small amount of material available and the fact that it was preserved no decision can be made. The chytrid in Lago Lugano has a campanulate sporangium (5·5–8μ maximum length, 3·5–6μ maximum breadth) attached to the host by an extramatrical, relatively thick, stalk-like portion which is usually set at right-angles to the long axis of the sporangium (Fig. 2H). The sporangium may develop by unequal growth of the zoospore but no unexpanded part of the original zoospore wall has been seen. The zoospores probably possess a large refractive globule in view of Fig. 2G. Dehiscence is by an operculum (2·5–6μ, Fig. 2H), and empty sporangia do not collapse. Asexually formed resting spores occurred with the sporangia on the host. They are subspherical to irregularly globose (8·0 by 7·5 to 10·5 by 8·5μ), contain several refractive globules and have a thick smooth wall (Fig. 2I). The endobiotic rhizoidal systems of this and the sporangia have not been detected.

The chytrid in Lago Maggiore agrees with that in Lago Lugano except for the much thicker wall to the resting spores (Fig. 2J), and the one or two globules within, differences which may be due to their greater maturity.

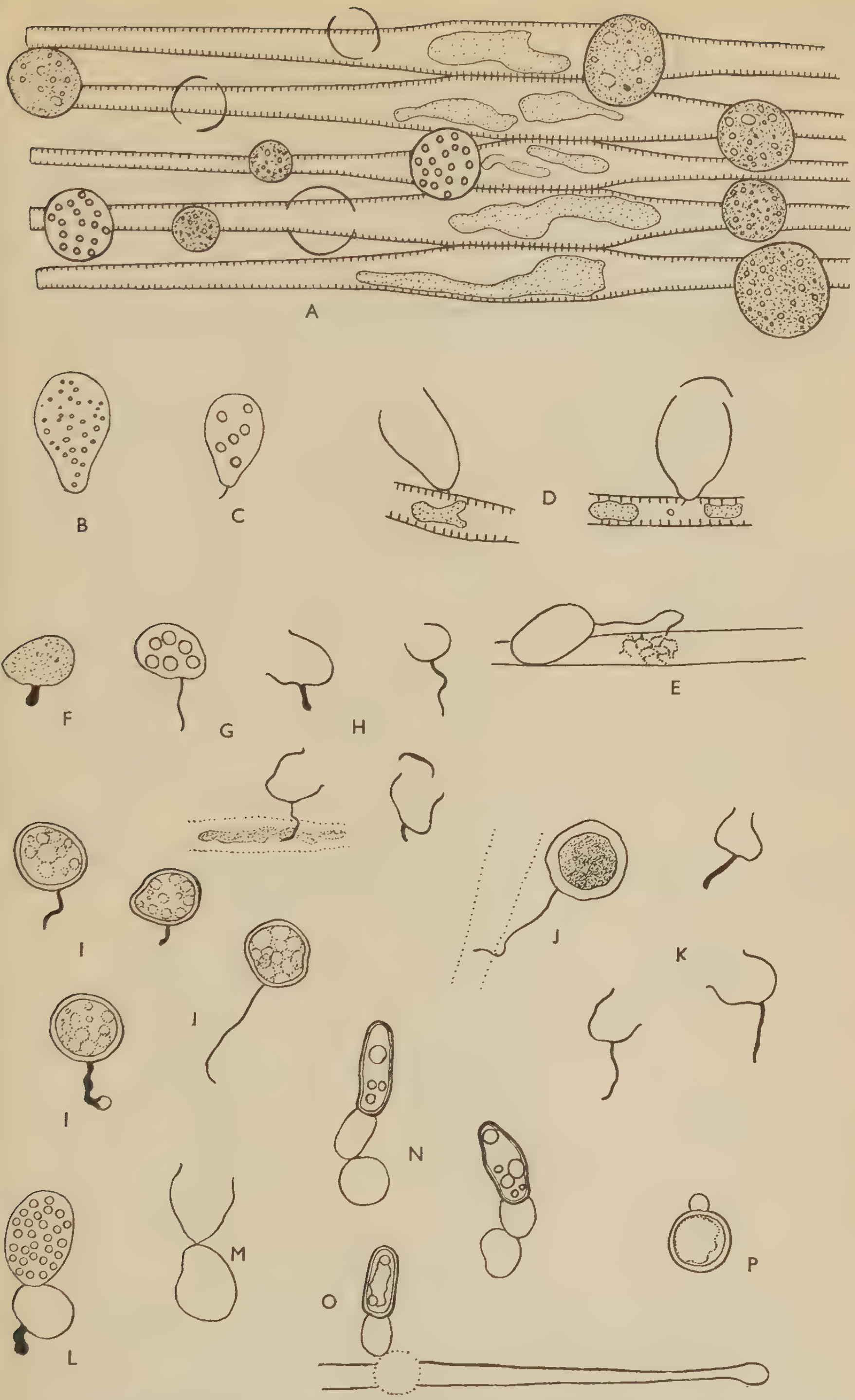

Fig. 2. Chytrids on *Fragilaria crotonensis* (Edw.) Kitton. A, *Rhizophidium fragilariae* Canter. B–E, *Chytridium versatile* Scherffel: B, immature; C, mature; D, empty sporangia; E, stained to show rhizoidal system. F–O, 'chytrid' species 3 from the Italian Lakes (see text). F–I, Lago Lugano: F, immature; G, mature and H, empty sporangia; I, four resting spores. J, K, Lago Maggiore: J, resting spore; K, three empty sporangia. L–O, *Septosperma anomala* (Couch) Whiffen, on species 3 and 4: L, mature; M, empty sporangia (Lago Lugano); N, resting spore from Lago Maggiore and O, from Erken. P, chytrid 'species 4' resting spore, Erken. A, D, ×1400; B, C, E–P, ×1066.

Species 4 (Fig. 2P)

In Erken spherical resting spores with an empty adherent male cell were found. Owing to infection with *Septosperma* no mature sporangia were seen and their morphology remains undetermined.

Table 3. *Incidence of epidemics of* Rhizophidium fragilariae *Canter an* Chytridium versatile *Scherffel on* Fragilaria crotonensis *(Edw.) Kitton between* 1946 *and spring* 1951 *inclusive*

	Rhizophidium and *Chytridium*		*Fragilaria*					
			Cells per ml.			Cells per col.		
Year	Epid. period	Max. inf.	Before	Max. inf.	After	Before	Max. inf.	After
			Windermere, north basin					
1948	26 July–16 Aug.	77	105	10	±1	38·7	16·4	10
			Windermere, south basin					
1946	25 Sept.–16 Oct.	65	244	25	1	35	25	12
1948	4–25 May	81	269	8	±1	48	7·7	3·2
1948	20 July–10 Aug.	77	855	105	5	46	7·4	10
1948	23 Sept.–5 Oct.	42	195	87	87	44	33·2	37
1949	6–19 Sept.	56	194	162	17	48·5	23	17
			Esthwaite Water					
1946	1–15 Oct.	59	150	186	48	38	37	24
1948	9 Apr.–12 May	87	234	77	±1	38·9	13·9	10
1948	7–27 Oct.	37	364	58	44	34·6	24·7	24·7
1949	20 June	43	—	—	—	—	—	—
1949	12–19 Sept.	29	48	74	55	48	25	20

(Explanation as for Table 2.)

Table 4. *Observed occurrence of fungal parasites on* Fragilaria crotonensis *(Edw.) Kitton in lakes other than those in Table 3*

Country	Lake	Date
England	Bassenthwaite	Oct. 1949
	Bassenthwaite	Sept. 1950
	Ullswater	Jan.–Aug. 1950
	Barn Elms Reservoir	Jan.–Feb. 1946
	*Rostherne Mere	Aug. 1922
	*Swithland Reservoir	Nov. 1946
	Swithland Reservoir	April 195
Ireland	*Lough Erne	Aug. 1951
Italy	*L. Maggiore	Jan. 1949
	*L. Maggiore	Apr. 1949
	*L. Lugano	May 1946
	*L. Lugano	May 1947
Sweden	*Erken	Sept. 1944

* Denotes preserved sample.

The hyperparasite *S. anomala* (Couch) Whiffen (Fig. 2L–O) was frequently observed in all the material of *Fragilaria crotonensis* except that from the English Lake District though it does occur there on *Chytriomyces tabellariae* Canter (1949). The range of measurements from all the localities is: sporangium, 8·0–12 μ long, 3·5–8·0 μ broad. Resting spore 8·5–11 μ long, 3·5–5·5 μ broad, excluding the sterile portion which is 4·0–7·0 μ long.

Fragilaria crotonensis does not occur in Blelham Tarn, and only rarely in appreciable density in Windermere north basin (e.g. 1948, Table 3), so that routine observations have only been possible in Windermere south basin and Esthwaite Water; in them, as in Ullswater and Bassenthwaite, it commonly reaches a maximum of up to 6000 cells/ml. during summer and autumn, while in spring it is usually but not always (Lund, 1950, p. 4) present in small numbers relative to those of *Asterionella*. During midwinter only scattered filaments occur (less than 1 cell/ml.). Its seasonal cycle is, therefore, similar to that recorded in many north temperate lakes (e.g. Wesenberg-Lund, 1908). It is a species characteristic of moderately to strongly eutrophic lakes. Practically nothing is known concerning the physico-chemical factors affecting its growth in nature. Chu's (1942, p. 321) ranges in concentration of nitrogen, phosphorus and silica, yielding active growth in culture, are in excess of those in the waters of these two lakes during the periods of active growth of this diatom. Einsele and Grim (1938) find that 10^6 cells contain 0·17–0·22 mg. SiO_2; a sample from Bassenthwaite gave a value of 0·19 mg./10^6 cells. Since, like *Asterionella* (Einsele & Grim, 1938; Lund, 1950), it appears that the amount of silica per unit surface area of cell is an approximately constant hereditary character, it is possible to estimate the maximum number of cells that can be produced in any one period. Moreover, the cells are unable to utilize appreciable quantities of silica when it is present in concentrations below 0·5 mg./l. (unpublished data, but see Lund, 1950, fig. 1 and p. 4).

In Fig. 3 the seasonal cycle of *Fragilaria crotonensis* in Esthwaite Water and Windermere south basin in 1948, is shown in relation to that of *Rhizophidium fragilariae* and *Chytridium versatile*. In Windermere (Fig. 3, lower graph) *Fragilaria crotonensis* showed three periods of active growth. In the first a maximum of approximately 400 cells per ml. was reached on 15 April and the numbers then remained stationary till 4 May. This may well have been connected with the reduction of the silica concentration to 0·2 mg./l. and the concomitant maximum of *Asterionella* (3000 on 21 April, 6000 cells/ml. on 4 May). A sharp decline in numbers occurred with the onset of a fungal epidemic, which by 19 May had led to the infection of 81 % of the population. The average number of live cells per filament fell from 69 on 4 May to 3·2 on 25 May. The second period of active growth began in June when the silica concentration of the water also rose markedly. By 12 July there were approximately 850 *Fragilaria* cells/ml. and the silica concentration had fallen to 0·4 mg./l. A catastrophic drop in numbers did not occur, however, until 27 July when fungal infection reached 77 % of the population. The average number of live cells per filament fell from 39 on 20 July to 8 on 10 August. A third period of growth from the end of August till the third week in September was correlated with another sharp rise in the silica concentration. After a maximum of approximately 200 cells/ml. on 21 September and 180 on 5 October a relatively small fall in numbers was correlated with a fungal epidemic less severe than the previous two, maximum infection being 32 % on 22 September and 42 % on 28 September, infection decreasing to 22 % between these dates. Thus the changes in algal numbers were paralleled by those in infection. The relative mildness of the epidemic is also portrayed in the number of live cells per filament which varied from

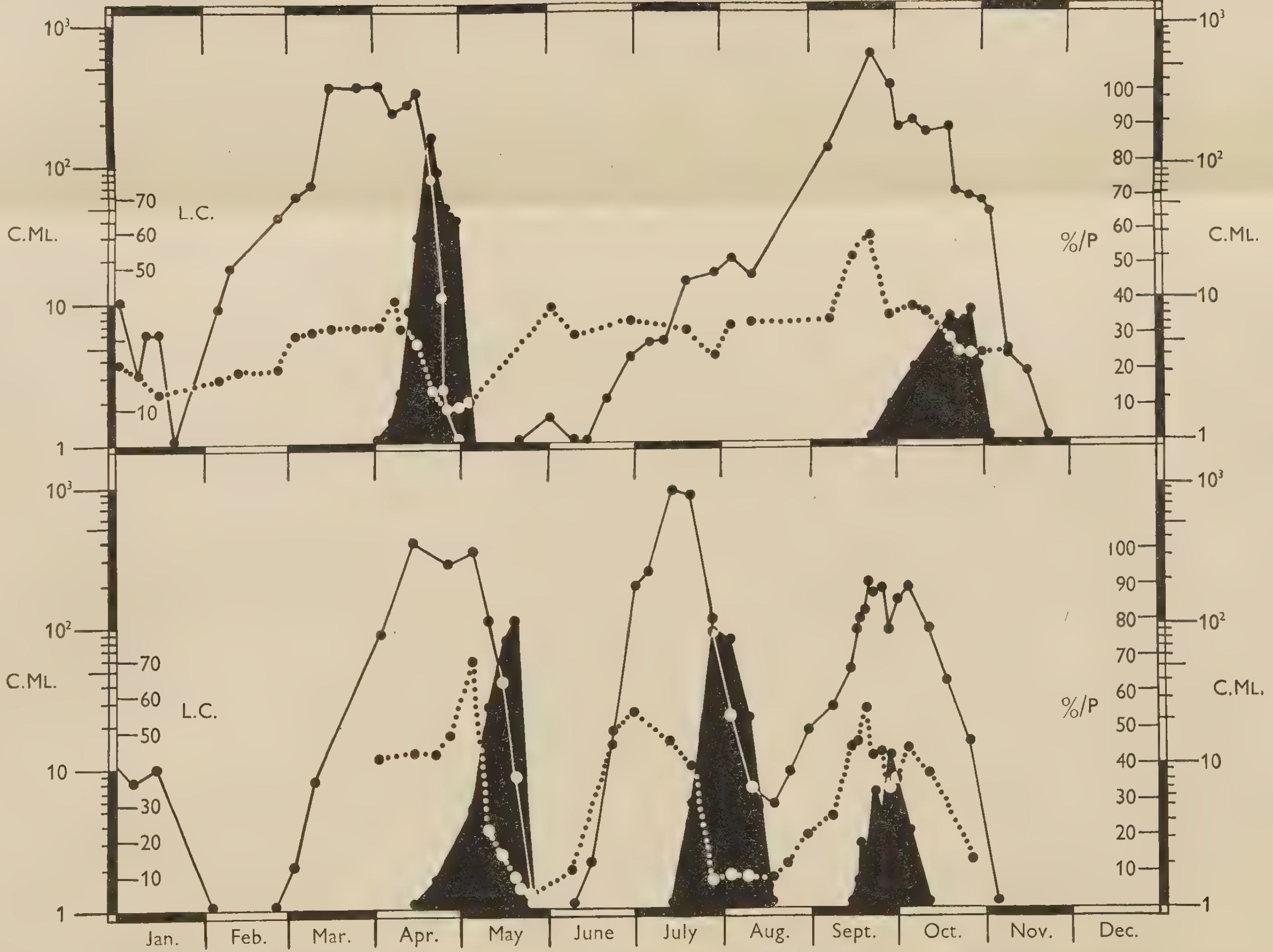

Fig. 3. The seasonal cycle in 1948 of *Fragilaria crotonensis* (Edw.) Kitton in relation to parasitism by *Rhizophidium fragilariae* Canter and *Chytridium versatile* Scherffel. Upper graph: Esthwaite Water; lower graph: Windermere south basin. Continuous line (C.Ml.), number of live cells of *Fragilaria* per ml. plotted on a log scale; *dotted line*, average number of live cells (L.C.) per *Fragilaria* colony; solid black, percentage of the ***Fragilaria*** population bearing parasites (%/P).

44 to 33. The final sharp decline in the numbers of *Fragilaria* was synchronous with the loss of thermal stratification.

In Esthwaite Water (Fig. 3, upper graph), as in Windermere, the spring increase in numbers in 1948 was earlier than usual, and after reaching about 400 cells/ml. on 16 March the population remained more or less static during the period of abundance of *Asterionella* until a severe epidemic occurred, 87 % of the population being infected on 20 April. This was followed by a catastrophic drop in diatom numbers and in live cells per filament. A second period of slow increase started in June, there being 550 cells/ml. by 22 September when there was almost complete loss of thermal stratification, followed by its partial renewal. A small fungal epidemic (34–37 % of the cells parasitized) may have hastened the sharp fall in numbers at the end of October.

Consideration of these changes in 1948, and those for other years summarized in Table 3, show that parasitism of *Fragilaria crotonensis* has features and effects similar to those described for *Asterionella*. In several cases, however, severe parasitism occurred at a time when either the chemical or physical conditions were unfavourable for the growth of *Fragilaria* and a cessation of its growth or a fall in numbers might have been expected. Nevertheless, the rate of decrease was certainly much increased. By contrast, in Esthwaite Water in 1949 (Lund, 1950; Canter & Lund, 1951) the infrequency of parasitism of *Fragilaria* in the presence of parasitism of *Asterionella* enabled the former to replace the latter as the predominant diatom species in the plankton. A similar change in dominance took place in Windermere south basin in July and in early September 1948 when the rate of increase of *Asterionella* was reduced by fungal epidemics (Table 1). The replacement of *Fragilaria* by *Asterionella* as a result of parasitism of the former has not been observed. It is clear that the seasonal cycle of *Fragilaria crotonensis* in these lakes cannot be interpreted without reference to parasitism.

PARASITES OF *MELOSIRA ITALICA* (Ehr.) Kütz.

Species 1. Zygorhizidium melosirae *Canter* (Fig. 4A–C)

This is the only parasite observed in Windermere, Esthwaite Water, Blelham Tarn, Ullswater, Haweswater, Loweswater and Loughrigg Tarn in the English Lake District, and in Swithland Reservoir and Lough Derg. In most of the Lake District lakes parasitism occurs sparingly throughout the period of occurrence of the host (October to April or May) yet only four epidemics have occurred though plentiful material has been available from all the Lake District lakes in which *Melosira italica* occurs. The effect of the fungus on the growth of the diatom, therefore, is usually negligible, and the sporadic nature of the occurrence of epidemics is even more marked than in the fungi previously described. *M. italica* differs from *Asterionella formosa* and *Fragilaria crotonensis* in that large populations occur on the deeper deposits during the period of its absence from the plankton (Lund, in preparation); the cells passing into a 'physiological' resting stage. Such resting cells have never been seen to bear parasites.

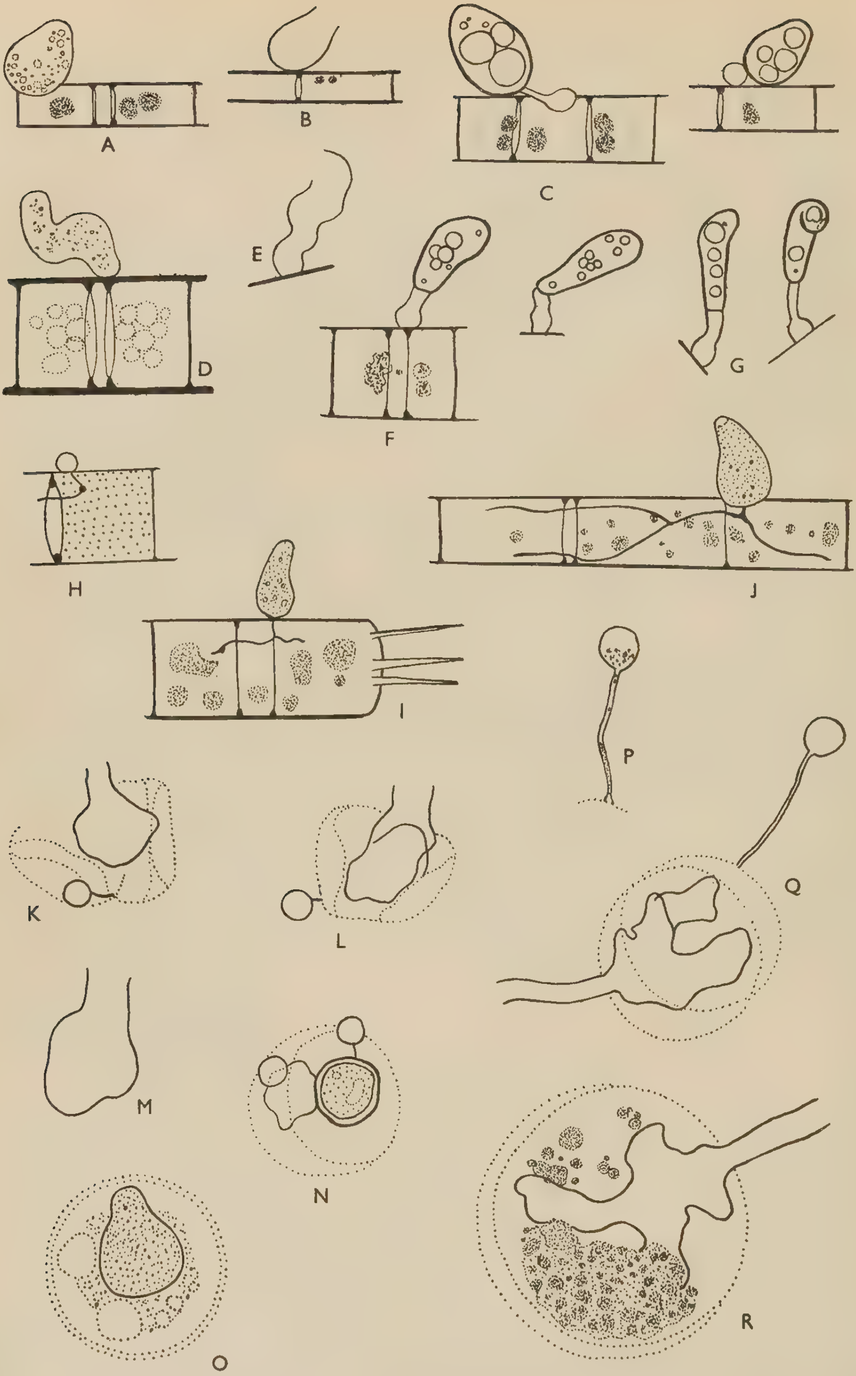

Fig. 4. A–J, chytrids on *Melosira* spp. A–C, *Zygorhizidium melosirae* Canter on *Melosira italica* (Ehr.) Kütz. from Esthwaite Water: A, immature and B, empty sporangia; C, resting spores. D–G, *Septosperma* sp. on *Melosira italica*: D, immature and E empty sporangium (Blelham Tarn); F, resting spores, Windermere; G, resting spores, Haweswater. H–J, ?*Rhizophidium fusus* (Zopf) Fischer on *Melosira granulata* (Ehr.) Ralfs from L. Oughter: H, encysted zoospore; I, J, immature sporangia with rhizoids. K–R, biflagellate fungi in *Cyclotella comta* (Ehr.) Kütz.: K–N, *Lagenidium cyclotellae* Scherffel, from Lago Maggiore; K–M, empty sporangia; N, resting spore; O, ?*L. cyclotellae* from Swithland Reservoir; P–R, fungus in *C. comta* from Neuenbergsee; P, encysted zoospore with germ tube; Q, R, empty sporangia. A–E, H–J, ×1066; F, G, ×970; K–R, ×835.

Species 2. Septosperma *sp.* (Fig. 4D–G)

Occasional specimens of an apparently saprophytic chytrid occur in the English Lake District (Blelham Tarn, Esthwaite Water, Windermere south basin, Haweswater, Loweswater and Ullswater) on cells of *Melosira* whose contents appear whitish. The sinuous sporangium (Fig. 4 D, E) 15μ long × 3·5μ broad which develops from the body of the encysted zoospore makes it easily recognizable. Resting spores were found associated with empty sporangia in Windermere south basin (Fig. 4F) and by themselves in Haweswater (Fig. 4G). They are two-celled, the distal portion (9–13μ high × 3·6–4·2μ broad) is thick-walled and broader than the proximal stalk-like portion (3·6–8μ high × 1·2–1·8μ broad).* The latter is often slightly swollen at its point of contact with the diatom wall. Neither the rhizoids nor dehiscence of the sporangium have been observed. The resting spore resembles that found in the genus *Septosperma*, the two other species of which parasitize other chytrids. Until more is known about the life history of this fungus it will be designated as *Septosperma* sp.

Species 3. ? Rhizophidium fusus (*Zopf*) *Fischer* (Fig. 4H–J)

A few specimens of yet another fungus were found on *Melosira granulata* (Ehr.) Ralfs in a preserved plankton sample from Lough Oughter (August 1951). The sporangium (Fig. 4I,J) somewhat resembles that described by Sparrow (1936, p. 439, fig. 4, *j*, *n*) as a form closely related to *Rhizophidium lagenula* (=*R. fusus* Sparrow, 1943, p. 202). The rhizoidal system is well developed (Fig. 4J), but no polyphagism has been noted. Neither empty sporangia nor resting spores were seen (dimension of sporangium 11·5μ high × 6μ broad).

Species 4

A spherical unidentifiable chytridiaceous fungus was observed on *Melosira italica* in a preserved sample from Nünivesi Vesanto dated July 1897. Other localities where chytrids have been seen on *Melosira* spp. but remain unidentified are Loch Erne and Llyn Maelog.

PARASITES OF *TABELLARIA*

Tabellaria Roth is under investigation by Miss B. M. Knudson of the Freshwater Biological Association, who informs us that the taxonomy of this genus needs revision and, for this reason, some of the records given in Table 5 refer merely to *Tabellaria* sp. while *T. fenestrata* (Lyngb.) Kütz var. *asterionelloides* Grun. here refers to the common planktonic forms normally occurring in stellate colonies (see Hustedt, 1938). Filamentous or more or less stellate colonies of forms which occur as epiphytes may also be found in the plankton (*Tabellaria* sp. in Table 6 includes these), and the occurrence of *Chytriomyces tabellariae* (Schröter) Canter on them is described in Canter (1949; 1951, p. 150).

Chytridium versatile Scherffel (Table 5) occurs very occasionally on *Tabellaria fenestrata* var. *asterionelloides* (Canter, 1950, p. 274) in Windermere and Ullswater, but the commoner fungus on this and members of the *T. flocculosa* complex is unidentified (Fig. 6 A–F). The spherical sporangia (5–13μ diameter, Fig. 6B–F) resemble those of *Rhizophidium planktonicum* and though, on the whole, they are somewhat larger and contain more zoospores (up to 40), this may be related to the cells of *Tabellaria* being larger than those of *Asterionella*. The rhizoidal system and resting spores have not been seen nor has dehiscence of the sporangium, though when empty (Fig. 6E, F) a small apical opening is visible. The zoospores (3μ diameter) have a single posterior refractive globule and flagellum (12μ long). The occurrence of this chytrid on *T. fenestrata* var. *asterionelloides* is rather sporadic and only two epidemics have been observed, three other epidemics have occurred on this and *Tabellaria* spp. found in the plankton, though Miss Knudson informs us that many of the cells of the

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* Measured above basal swelling.

Table 5. *The occurrence of* Rhizophidium *sp. and* Chytridium versatile *on* Tabellaria fenestrata *var.* asterionelloides

	Rhizophidium sp.			
Lake	1948	1949	1950	1951
Esthwaite Water	11 Feb.–13 May	5–27 Apr., 7 Nov.	9 Jan.–22 May, 30 Oct.	—
Windermere, south basin	3–25 May, 3 Aug.–26 Oct.	17–30 May	8–15 May	—
Windermere, north basin	12 Apr.–21 May	28 Mar.–9 May, 5 Dec.	1 May	—
Ullswater, west	No collections	13–18 Apr.	1 Mar.–24 May	29 May
Ullswater, east	No collections	30 Mar.–28 Apr.	2 Feb.–26 Apr.	5 Feb., 17 Oct.
Bigland Tarn	No collections	No collections	—	23 Mar.

	Chytridium versatile					
	1946	1947	1948	1949	1950	1951
Windermere, south basin	8 Oct.	11 Nov.	30 June–3 Aug.	16 Aug.–25 Aug.	3 Oct.	18 Oct.–19 Nov.
Ullswater, east	No collections			13 Oct.	—	—

Table 6. *Records of fungal epidemics on diatoms other than* Asterionella formosa *and* Fragilaria crotonensis

Host	Parasite	Max. inf.	Lake	Date
Melosira italica	*Zygorhizidium melosirae*	+30	Esthwaite Water	1 Jan. 1948
		+50	Loughrigg Tarn	Jan. 1950
		±25	Ullswater, west	Feb. 1951
		±25	Ullswater, east	Jan. 1951
Stephanodiscus astraea var. *minatula*	*Z. planktonicum*? (see p. 33)	+50	Windermere, south basin	Feb.–Mar. 1951
Synedra acus var. *angustissima*	*Z. planktonicum*	82	Rotsee	July 1948
		58	Lugano	July 1946
Tabellaria fenestrata var. *asterionelloides*	*Rhizophidium* sp.	32	Esthwaite Water	Apr. 1950
		±25	Ullswater, east	Apr. 1948
		58	Ullswater, east	Apr.–May 1949
Tabellaria spp.	*Rhizophidium* sp.	34	Ullswater, west	Apr.–May 1949
Tabellaria spp.	*Chytriomyces tabellariae*	52	Derwentwater	Apr.–May 1949
Rhizosolenia eriensis	Unidentified	37	Coniston Water	Oct. 1951

(*Max. inf.* maximum percentage of host population infected. The western and eastern parts of Ullswater have a similar plankton but the development of the species differs in time.)

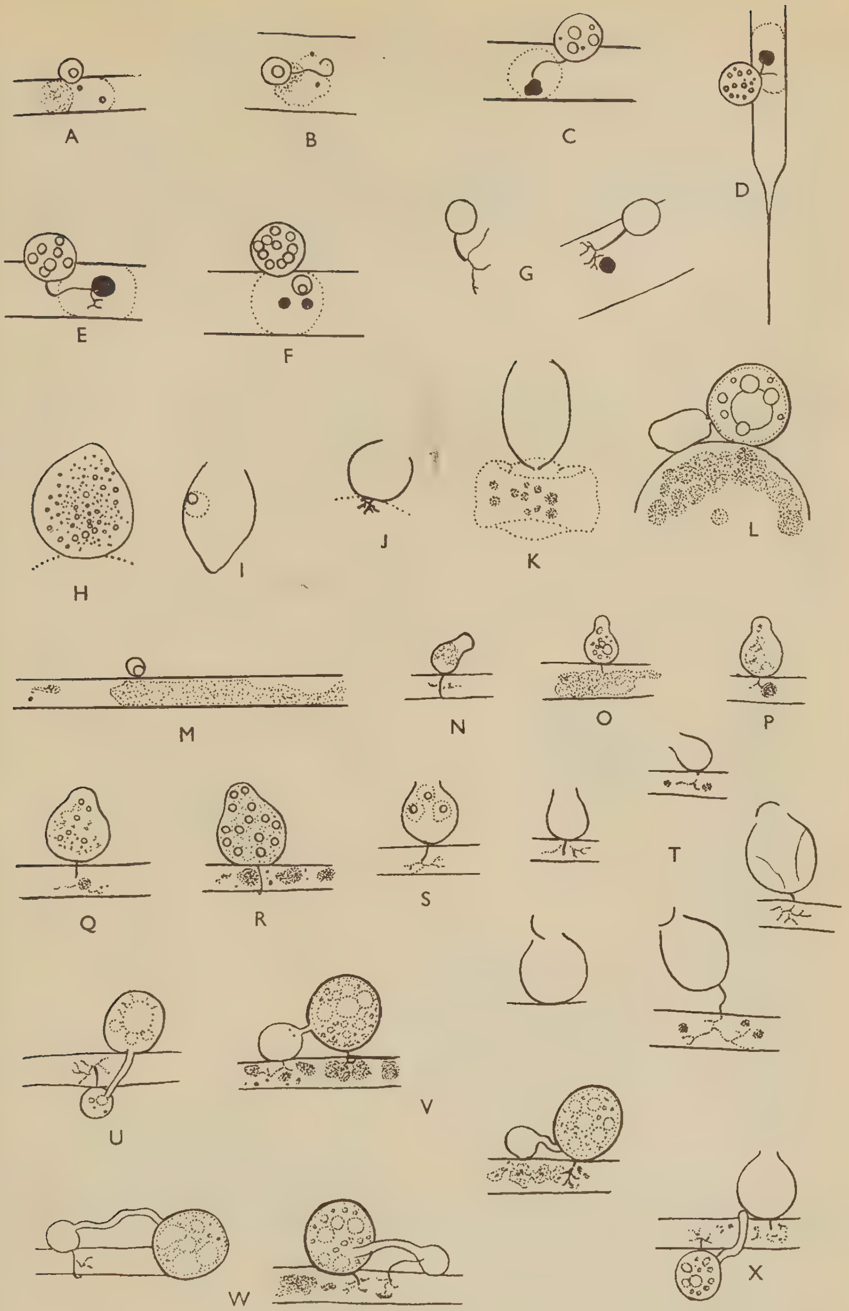

Fig. 5. A–G, chytrid parasitizing *Rhizosolenia eriensis* H. L. Smith from Coniston Water: A, encysted zoospore; B, zoospore with extramatrical germ tube; C, D, immature and E, F, mature sporangia; G, two thalli stained in aceto-carmine to show internal rhizoidal system. H–L, *Zygorhizidium* sp. on *Stephanodiscus astraea* (Ehr.) Grun. var. *minatula* (Kütz.) Grun. from Windermere: H–K, sporangia; L, resting spore with adherent male cell. M–X, *Zygorhizidium planktonicum* sp.n. from Rotsee: M, encysted zoospore; N–T, sporangia; N–Q, young; R, mature. S, dehisced with the residual zoospores; T, five empty ones, three with adherent lid; U–X, sexual reproduction: U, young male and female thalli united by a conjugation tube; V, two resting spores, male cell with short conjugation tube; W, two resting spores; male cells with extramatrical germ thread and intramatrical rhizoidal system; X, male thallus apparently functioning as a sporangium. A–G, L, M–X, ×1340; H–K, ×970.

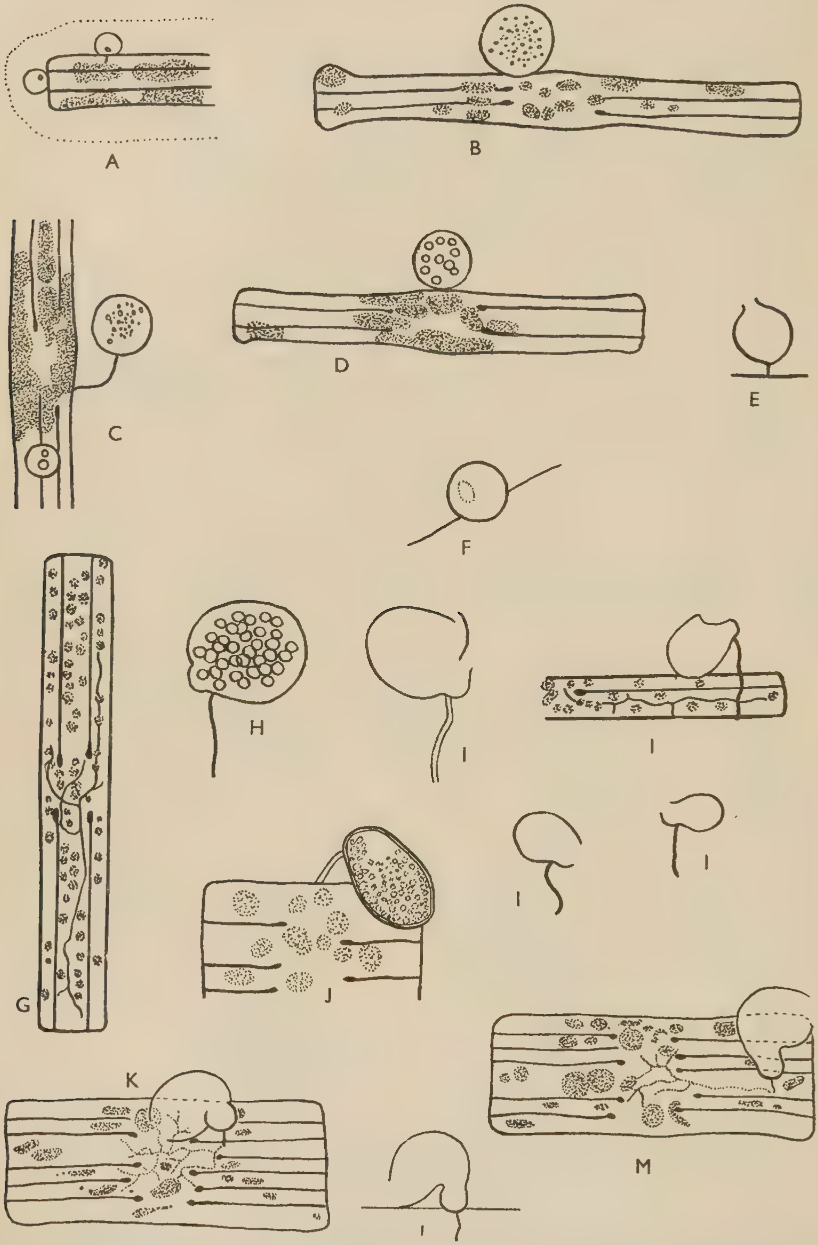

Fig. 6. A–F, *Rhizophidium* sp. on *Tabellaria fenestrata* var. *asterionelloides*, drawings made from cells of attached species found in the plankton of Esthwaite Water; A, encysted zoospore; B, C, immature; D, mature and E, F, empty sporangia, dehiscence pore dotted in F. G–J, *Chytriomyces tabellariae* (Schröter) Canter on *Tabellaria* spp.; G, rhizoidal system; H, mature sporangium; I, empty sporangia; J, resting spore. K–M, fungus resembling *Rhizidiopsis* (see p. 31) from reed population in Blelham Tarn. I, J, × 1400; A–F, H–M, × 1070; G, I, × 746.

latter were probably derived from attached populations (Table 6). Yet another chytrid (Fig. 6K–M), hitherto only observed on the *T. flocculosa* complex (in Ullswater and Blelham Tarn and Esthwaite Water), occurred on *Tabellaria fenestrata* var. *asterionelloides* in Windermere south basin during November 1951. Details of the life history are not complete. The sporangium resembles an operculate form of *Rhizidiopsis emmanuelensis* Sparrow. The rhizoidal system too is of a similar nature. No resting spores were found.

PARASITES OF *RHIZOSOLENIA*

Rhizosolenia eriensis H. L. Smith (and its variety *morsa* W. & G. S. West) occurs in many of the lakes in the English Lake District though rarely in abundance. Like so many plankton diatoms it is parasitized by an epibiotic chytrid with a spherical sporangium (Fig. 5A–G). Though widespread (Table 7) it has only once reached epidemic proportions (Coniston Water 1951, Table 6). If the zoospore of this chytrid settles on the host wall in the immediate neighbourhood of a chromatophore germination is by a thread which penetrates the cell directly, but if it settles some distance away this thread grows along the outside of the wall until it is opposite a chromatophore at which point penetration of the cell occurs. The internal rhizoidal system consists of a few short, branched threads (Fig. 5G) which appear to be confined to the pigmented area of the cell. Mature sporangia (4–6·5μ diameter) contain about 8–12 conspicuous refractive globules (Fig. 5E, F), each indicating the position of a zoospore. Neither dehiscence nor empty sporangia have been seen; it may be that the extremely delicate wall deliquesces on dehiscence. No resting spores have been seen.

Table 7. *The occurrence of the chytrid parasitizing* Rhizosolenia eriensis *in the English Lake District*

Lake	Date	Lake	Date
Blelham Tarn	20 May, 19 Nov. 1947	Ennerdale	3 Nov. 1948
	30 Sept.–13 Oct., 2 Dec. 1948	Loweswater	4 May 1950
	3 Apr., 8 May 1950		
	3 Apr., 8 May 1950		11 Apr. 1951
	3 Sept.–12 Nov. 1951	Coniston Water	10 Aug.–2 Nov. 1949
Windermere, south basin	2 Feb.–10 May 1949		22 Mar.–17 May 1950
			28 Sept.–25 Oct. 1950
Windermere, north basin	13–20 Sept. 1948		24 Oct. 1951
	4–9 May, 1949	Haweswater	11 Apr. 1949
Ullswater	1 Oct. 1948		26 Mar. 1951
	29 May 1951	Bassenthwaite	13 Sept. 1950
Crummock Water	10 Feb. 1949		

PARASITES OF *CYCLOTELLA*

Cyclotella spp. occur in the nannoplankton of all the English Lake District lakes, but as the investigations on parasitism were largely carried out on samples collected by net, observations were somewhat limited. A spherical epibiotic chytrid was observed on one or more of the following: *C. comensis* Bachmann, *C. comta* (Ehr.) Kütz, *C. praetermissa* Lund and *C. glomerata*

Bachmann in Windermere, Esthwaite Water, Blelham Tarn, Ullswater, Haweswater and Crummock Water. In Swithland Reservoir a few specimens of this fungus have been found on *C. comta*. In Haweswater a polyphagoid chytrid was observed once on the colonial *C. praetermissa*.

Internal fungi (Fig. 4K–R) have been observed in *Cyclotella* in preserved material from Neuenbergsee, July 1948, Maggiore, June 1949, and Swithland Reservoir, April 1950. Although no zoospores were seen there is no doubt that the fungi concerned belong to the Biflagellatae.

The fungus in Lago Maggiore resembles *Lagenidium cyclotellae* Scherffel. There is a persistent zoospore cyst (4–4·75μ in diameter) with an infection thread (Fig. 4K, L). Although the connexion between the latter and the thallus could not be determined, it seems likely that the thallus is continuous with this tube. The thallus is sack-like (Fig. 4K–M) (12·5 × 12·5–14 × 18μ) with a short broad exit tube which protrudes between the separated valves of the diatom (Fig. 4K, L). The resting spore is sexually formed, subspherical-oval in shape (Fig. 4N) (10 × 12·5–11 × 9·5μ) with a thick smooth wall, and completely fills the gametagium. The male thallus was difficult to observe and, as noted for *L. cyclotellae*, no fertilization tube was seen. Although the observations are meagre, it seems highly likely that this is *L. cyclotellae*. It is possible that this is the fungus found in *Cyclotella comta* in Swithland Reservoir (Fig. 4O). However, owing to its scarcity and bad preservation of the material it could not definitely be assigned to *Lagenidium cyclotellae*. The fungus from Neuenburgsee differs from that just described in several ways, and further specimens must be examined before its affinities can be discussed. The persistent cyst of the zoospore is larger (5·5 × 6·3μ) (Fig. 4P, Q) than that of *L. cyclotellae*, and there is a long infection tube (20μ) whose length is probably determined by the width of mucilage surrounding the diatom. The thallus (Fig. 4Q, R) is lobulate (22–31μ broad excluding length of exit tube) with an exit tube (16·5μ long × 4–4·5μ broad). The valves of the diatom do not appear to be pushed apart as in the material from Maggiore. Whether this is a different fungus or one modified by the greater size of the diatom cell and its surrounding mucilage remains unknown. The difference in size of the zoospore cysts does suggest that a second fungus is involved.

PARASITES OF *STEPHANODISCUS*

Stephanodiscus astraea (Ehr.) Grun. var. *minatula* (Kütz) Grun. is the only member of the genus occurring in Windermere, Esthwaite Water, Ullswater and Derwentwater, and it may be severally infected by an operculate chytrid (Fig. 5H–L) with a sexually formed resting spore. While some sporangia resembled those of *Zygorhizidium planktonicum* (Fig. 5J), others varied from urn-shaped to cylindrical (Fig. 5K). The sporangia are 11–21μ high and 12–13μ broad. The internal branched rhizoidal system forms a short tuft arising from the single thread penetrating the diatom. The zoospores are matured within the sporangium so that, after the first few have emerged, those remaining move actively within. The spherical zoospore (2·5μ diameter) has a conspicuous anterior oil globule and shows a smooth gliding movement with frequent changes in direction. Conjugation resembles that of *Z. planktonicum* in that the male thallus (Fig. 5L) (3·5 μ high; 5·5 μ broad) appears to have enlarged from the size of the original zoospore, but in this and other details many more specimens must be examined before the systematic position of the fungus can be determined. It is possible, however, that it is *Z. planktonicum*, the slight differences in size and shape being related to the difference in size of the host cell and its surrounding mucilage.

Sparrow (1951) has described a severe epidemic of *Podochytrium cornutum* Sparrow on *Stephanodiscus niagarae* Ehr., a diatom which is not recorded for Britain. Up to sixty fungal infections may occur on one cell but death is caused by a single infection. Sparrow states that 'as might be expected, host cells attacked by many parasites were stunted in comparison with cells with only a few parasites'. In view of the construction and mode of division of the diatom cell this result seems most unexpected and has never been observed by us for any diatom infected by a fungus.

PARASITES OF *SYNEDRA*

In Rotsee in August 1948 and Lago Lugano in July 1946 *Synedra acus* Kütz. var. *angustissima* Grun. was infected by a new species (*Zygorhizidium planktonicum*) (Fig. 5 M–X) to the extent of over 80 and 50 % respectively. The zoospore of this fungus encysts either on the diatom wall (Fig. 5 M) or on mucilage surrounding it, and penetration of the host cell is by a fine thread, the length of which depends on the distance of the zoospore from the girdle, through which penetration occurs. Immediately below the wall this thread forms a densely branched but short rhizoidal system (Fig. 5S, T). The zoospore enlarges into an obpyriform* sporangium, the apex surmounted by a convex operculum (Fig. 5T). The mature sporangium contains three to twenty refractive globules of equal size, each indicating the position of a zoospore. As they were few in number, measurements were made on empty sporangia (4–8 μ high; 3–7 μ diameter) which do not collapse and to which the operculum (2–3 μ diameter) often remains adherent (Fig. 5T). The zoospore (2 μ diameter) contains a single large refractive globule.

The resting spore is formed sexually (Fig. 5U–W). The male cell makes contact with the female through a conjugation tube whose length (up to 10 μ) depends on their distance apart. When the rhizoidal system of the sexual thalli is visible it is similar to that of the sporangium (Fig. 5 W). The empty male thallus associated with the resting spore varies from 2·5 to 4 μ high and 4 to 4·5 μ broad, and so cannot be regarded as an unaltered encysted zoospore. It is not known whether growth occurs before or after contact with the female, or if the process is isogamous or anisogamous. The mature resting spore (7–8 μ high; 6·5–7·5 μ broad) is subspherical to oval with a thick, smooth wall; it contains several refractive globules of unequal size. A male thallus may be converted into a sporangium if the conjugation tube does not make contact with a female (Fig. 5X) as is recorded for *Z. willei* Löwenthal, *Z. parvum* Canter and *Rhizophidium columnaris* Canter.

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* Some botanists use the term pyriform where others use obpyriform and vice versa. Pyriform is here used when the pear-shaped structure is broadest and obpyriform when it is narrowest at the apex (cf. Blackwell, 1949).

As noted earlier (p. 15), what is assumed to be this fungus was found on *Asterionella*. Except for the fact that no operculum has as yet been observed on *Asterionella*, and the rhizoidal system of the male is not so conspicuous, there are no significant differences. The organism under consideration is placed in the operculate genus *Zygorhizidium*.

Z. melosirae Canter (1950) has a similar sexual process and sporangium, but the resting spore differs in shape and the male cell is essentially an unaltered encysted zoospore. Since there is no other species to which this can be assigned it is diagnosed as new as follows by the first author.

Zygorhizidium planktonicum Canter, sp.n.

Thallus monocentric consisting of an epibiotic obpyriform sporangium (4–9μ high; 3–8μ broad) whose apex functions as an operculum (2–3μ diameter) which often remains adherent after dehiscence; there is a short richly branched internal rhizoidal system. Sporangium developed by direct enlargement of the zoospore. Resting spore (7–8 × 6·5–7·5μ) with a thick, smooth wall and containing several refractive globules; formed by the fusion of two thalli through a conjugation tube (to 10μ long). Empty male thallus (2·5–4 × 4–4·5μ). Rhizoidal system of male and female thallus identical with that of sporangia.

On *Synedra acus* var. *angustissima* in Rotsee and Lago Lugano, Maggiore, Mergozzo. ? On *Asterionella formosa* in Malham Tarn, Lough Derg, Lough Talt and Sarnersee.

Material of the type collection (Rotsee) has been deposited in the Laboratory of the Freshwater Biological Association.

Thallus monozentrisch, aus einem epibiotischen verkehrt birnenförmigen Sporangium (4–9μ hoch; 3–8μ breit) und viel verzweigten inneren Rhizoidsystem bestehend. Sporangium durch vergrosserung der volkommene Zoospore enstehend; Öffnung apikal mittels eines oft anhängenden Deckels (2–3μ breit). Dauerspore (7–8 × 6·5–7·5μ) rundlich, Wand dick, glatt; Inhalt aus mehreren lichtbrechenden Tröpfchen bestehend. Männliche Pflanzen (entleert, 2·5–4 × 4–4·5μ) mittels eines langen oder kurzen Kopulationsschlauches (bis auf 10μ lang) mit den weiblichen Pflanzen kopulierend. Rhizoidsystem der männlichen und weiblichen Pflanze identisch mit den der Sporangia.

Auf *Synedra acus* var. *angustissima* im Rotsee, L. Lugano, Maggiore und Mergozzo.

Auf *Asterionella formosa* in Malham Tarn, L. Derg, L. Talt, und Sarnersee.

The cells of a number of attached *Synedra* species are occasionally encountered in the plankton, and one undetermined species sometimes occurs in abundance in the plankton; on this a few sessile spherical immature fungal sporangia have been observed.

BACTERIA. FLUORESCENCE ANALYSIS

The occurrence of what appear to be bacteria has been noted on the sporangia of *Rhizophidium planktonicum* (Fig. 1 V–X) and the sporangia and resting spores of *Zygorhizidium melosirae*. Where large numbers occur on a sporangium, it is dead, and more or less disintegrated contents may remain within it. Whether the bacterium causes the death of the fungus or whether it is a saprophyte is unknown, but it does not occur on dehisced sporangia. The bacterial cell is kidney-shaped and, after staining, is seen to be embedded in mucus; it is Gram-negative.

For observations with ultra-violet light an outfit marketed by Cooke, Troughton and Sims was used in conjunction with a Pointolite or similar lamp. This consists of a filter to cut out visual light from an ordinary microscope, an aluminium mirror and a yellow filter in the eye-piece. For the present work an ordinary glass mirror was also found to be suitable. The first series of observations was made with acridine orange at a dilution of 1 in 20,000 as recommended by Strugger (1948). A second series carried out more than a year afterwards was not successful until the dilution was altered to 1 in 80,000. The reason for this is unknown. With acridine orange the nucleus of a diatom such as *Asterionella* or *Tabellaria* can be seen as a green ellipsoid body whose identity can be checked by fixation and staining with nuclear stains. The nucleus of a cell bearing a single encysted zoospore is similar to that of uninfected cells, but as the zoospore develops into the sporangium the chromatophores become progressively disorganized and the nucleus becomes more and more difficult to see in ultra-violet light, being generally a faintly stained body not sharply distinct from the rest of the contents. By the time mature or dehisced sporangia have developed the nucleus is rarely detectable. These are just the series of changes one would expect as a result of parasitism so that, in cases of doubt, this method is useful for distinguishing between parasitic and saprophytic species. The results of observations on a population in Blelham Tarn are shown in Table 8.

Table 8. *Changes in the appearance of the nucleus of* Asterionella formosa *in relation to the development of* Rhizophidium planktonicum *as observed in ultra-violet light after staining with acridine orange*

Nucleus	+	±	−
Cells uninfected	301	2	0
Cells bearing zoospores	38	3	5
Cells bearing young sporangia	22	15	2
Cells bearing mature sporangia	1	4	22
Cells bearing empty sporangia	0	0	27

(+, nucleus a clearly delimited bright green body; ±, nucleus pale, not sharply delimited from the other cell contents; presence often doubtful; −, no nucleus.)

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APPENDIX

Lakes and smaller bodies of water from which were collected samples containing fungi parasitic on plankton diatoms:

ENGLAND

The Lake District

- Bassenthwaite
- Blelham Tarn
- Brothers Water
- Buttermere
- Coniston Water
- Crummock Water
- Derwentwater
- Elterwater
- Ennerdale Water
- Esthwaite Water
- Grasmere
- Haweswater
- Loughrigg Tarn
- Loweswater
- Middlerigg Tarn
- Overwater
- Rydal Water
- Thirlmere
- Ullswater

Cheshire

- Rostherne Mere

Lancashire

- Bigland Tarn

Leicestershire

- Swithland Reservoir

London

- Barn Elms Reservoir

Yorkshire

- Malham Tarn

Westmorland

- Sunbiggin Tarn

EIRE

- L. Erne
- L. Derg
- L. Oughter
- L. Currane
- L. Talt
- L. Glencar

FINLAND

- Tuusulanjarvi
- Nünivesi Vesanto

FRANCE

- L. Léman

HOLLAND

- Loosdrechtsee Plassen

ITALY

- L. Lugano
- L. Maggiore
- L. Mergozzo
- L. Como

NEW ZEALAND

- Lake Clearwater

SCOTLAND

- L. Lochy
- L. Tay
- L. Cullin
- L. Uanagan
- L. Earn

SWEDEN

- Erken

SWITZERLAND

- Rotsee
- Bielersee
- Sarnersee
- Baldeggersee
- Zürcher Obersee
- Neuenbergsee

WALES

- L. Maelog

REFERENCES

BLACKWELL, E. (1949). Terminology in *Phytophthora*. *Mycol. Pap.* no. 30, 1–23.

CANTER, H. M. (1949). Studies on British chytrids. IV. *Chytriomyces tabellariae* (Schröter) n.comb. parasitized by *Septosperma anomala* (Couch) Whiffen. *Trans. Brit. mycol. Soc.* **32**, 16–21.

CANTER, H. M. (1950). Fungal parasites of the phytoplankton. I. (Studies on British Chytrids. X.) *Ann. Bot., Lond.*, N.S., **14**, 263–289.

CANTER, H. M. (1951). Fungal parasites of the phytoplankton. II. (Studies on British Chytrids. XII.) *Ann. Bot., Lond.*, N.S., **15**, 129–156.

CANTER, H. M. & LUND, J. W. G. (1948). Studies on plankton parasites. I. Fluctuations in the numbers of *Asterionella formosa* Hass., in relation to fungal epidemics. *New Phytol.* **47**, 238–261.

CANTER, H. M. & LUND, J. W. G. (1951). Studies on plankton parasites. III. Examples of the interaction between parasitism and other factors determining the growth of diatoms. *Ann. Bot., Lond.*, N.S., **15**, 359–371.

CHU, S. P. (1942). The influence of the mineral composition of the medium on the growth of planktonic algae. Pt. 1. Methods and culture media. *J. Ecol.* **30**, 284–325.

DeBach, P. & Smith, H. S. (1947). Effects of parasite population density on rate of change of host and parasite populations. *Ecology*, **28**, 290–298.

Einsele, W. & Grim, J. (1938). Über den Kieselsäuregehalt planktischer Diatomeen und dessen Bedeutung für einige Fragen ihrer Ökologie. *Z. Bot.* **32**, 545–590.

Hustedt, F. (1932). Die Kieselalgen Deutschlands, Österreichs und der Schweiz. Rabenhorst's *Kryptogamenflora*, **7**, Teil 1.

Hustedt, F. (1938). Die Kieselalgen Deutschlands, Österreichs und der Schweiz. Rabenhorst's *Kryptogamenflora*, **7**, Teil 2.

Lund, J. W. G. (1949). Studies on *Asterionella formosa* Hass. I. The origin and nature of the cells producing seasonal maxima. *J. Ecol.* **37**, 389–419.

Lund, J. W. G. (1950). Studies on *Asterionella formosa* Hass. II. Nutrient depletion and the spring maximum. Pt. 1. Observations on Windermere, Esthwaite Water and Blelham Tarn. *J. Ecol.* **38**, 1–14.

Skuja, H. (1948). Taxonomie des Phytoplanktons einiger Seen in Uppland, Schweden. *Symb. bot. upsaliens*, **9**, (3).

Sparrow, F. K. (1936). A contribution to our knowledge of the aquatic Phycomycetes of Great Britain. *J. Linn. Soc. (Bot.)*, **50**, 417–478.

Sparrow, F. K. (1951). *Podochytrium cormutun* n.sp., the cause of an epidemic on the planktonic diatom *Stephanodiscus*. *Trans. Brit. mycol. Soc.* **34**, 170–173.

Strugger, S. (1948). Der Gegenwärtige Stand der Forschung auf dem Gebiet der fluoreszenmikroskopischen Untersuchung der Bakterien. *Mikroskopie*, **3**, 23–38.

Wesenberg-Lund, C. (1908). *Plankton Investigations of the Danish Lakes*. Copenhagen.

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BACTERIAL DISEASES OF STONE-FRUIT TREES IN BRITAIN

IX. BACTERIOSIS OF APRICOT

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(With Plate 1)

A hitherto unrecorded bacterial disease of apricots, caused by *Pseudomonas mors-prunorum* Wormald, involving the leaves, shoots, and older wood, is described in detail.

Differences in the relative amounts of acid produced on lactose and maltose is suggested as an additional criterion for distinguishing *Ps. mors-prunorum* from the related stone-fruit pathogen, *Ps. prunicola* Wormald. The existence of biologically specialized forms of *Ps. mors-prunorum* was demonstrated in cross-inoculation experiments with cherry, plum and apricot strains of this organism. The relation of the bacterial die-back to other forms of apricot die-back is discussed. The apricot bacteriosis is compared with that of cherry and plum, and the importance of environmental factors in the epidemiology of the shoot wilt considered briefly.

In early May 1949 a severe leaf spotting was observed on young apricots at East Malling. Associated with this was a 'die-back' of the 1-year-old branches and, following a period of wet, cold weather later in the month, an extensive wilting of the young shoots. Bacterial masses were detected microscopically in the necrotic tissues of the leaves, branches and shoots, and isolations from each of these organs yielded the same bacterium which on nutrient agar + 5 % sucrose formed colonies with similar form and structure to those of *Pseudomonas mors-prunorum* Wormald and *Ps. prunicola* Wormald.

Ps. mors-prunorum causes Bacterial Canker of plum, cherry, and related hosts including peach (*Prunus persica*), almond (*P. amygdalus*) and the purple-leaved plum (*P. pissardi*) (Wormald, 1931, 1938*a*, *b*, 1942). In plum, cherry and almond, the winter canker phase of this disease is associated with a leaf spot, caused by the same organism, and believed to be an important over-summering stage of the disease. In certain years when environmental conditions are suitable, the young shoots of these three hosts may also be attacked. No comparable stages in the leaves and shoots of peach and the purple-leaved plum have been recorded. *Ps. prunicola* causes a similar canker and leaf spot of cherry, but, apart from occasional attacks on the green shoots of plum, it has not so far been recorded on any other species of *Prunus*.

No bacterial disease of apricot has hitherto been recorded in Britain, but in America it is an important host of *Xanthomonas pruni* (Smith) Dowson, which attacks the leaves, shoots and fruits. In that country, too, the apricot and other stone-fruits suffer a Bacterial Canker disease similar to that in Britain, and caused by *Pseudomonas cerasi* Griffin. This organism and *Ps. prunicola* are now believed to be identical with, or special forms of, *Ps. syringae* van Hall, the lilac blight organism (Wilson, 1931, 1936).

The occurrence in Britain of an apricot disease of probable bacterial origin was important not only for its bearing on the control of the bacterial diseases of other stone-fruits, but because it offered an explanation of the die-back to which apricots have long been susceptible in this country. The etiology of the disease was therefore investigated.

THE DISEASE

The disease was first observed in a mixed nursery of 2 to 4-year-old trees containing the varieties Moorpark, Early Moorpark, Ansu, Croughton and Bradbourne. In another locality, 3-year-old trees of a seedling variety were also affected.

Individual leaf infections appeared first as small reddish purple spots with necrotic centres. These enlarged to 0·5–3 mm. and the surrounding pigmentation disappeared. In the variety Ansu, however, the purple coloration was both conspicuous and persistent, and frequently coalesced from adjacent spots to form irregular patches enveloping two or more of the spots. In other varieties, particularly on maturer leaves, the pigmentation was either absent or replaced by a faint yellow halo. The spots were marginal or superficial, and occasionally occurred in a linear series resulting from infection drops channelled down the main vein of the leaf (Pl. 1, fig. 1).

Diseased shoots presented two distinct symptom pictures, depending on the position of the original point of infection. If this was near the succulent apex, the shoot was girdled and a typical 'tip-wilt' resulted. The girdling lesion then advanced for varying distances down the longitudinal axis, causing defoliation at each successive internode. The entire upper limits of the shoot were thus killed, and secondary shoots frequently developed from axillary buds below the limits of the lesion. Infections of the lower and harder tissues, however, resulted only in localized lesions extending from 3 to 40 mm. along the longitudinal axis of the shoot, but never girdling it. These lesions eventually blackened and split to form elliptical cankers; when these were large the shoot became strongly recurved towards the infected side. Severe defoliation also occurred when shoots sustained several of these localized lesions, even although the apices remained healthy (Pl. 1, fig. 2). Globules of bacterial ooze exuded from infected shoots kept under damp conditions. These were not seen in the field, but wax-like scales picked off diseased shoots proved to be bacterial masses dried to the underside of some homogeneous material, presumably cutin. Pure cultures were readily established from these.

The die-back was confined to 1-year-old branches. These were girdled by lesions from 12 to 20 cm. long. The positions and extent of the lesions were marked by a characteristic shiny, wrinkled appearance and chocolate brown colour of the periderm and buds. Smaller lesions occurred below the main one and were invariably located round the base of a dead bud. Examination showed that most of these buds had not long been invaded, and did not therefore appear to be the original points of infection. These may have been the leaf scars subtending the buds, as is frequently the case with cherry (Crosse, 1951).

Bacteria were distributed in isolated pockets in the dead cortical tissues of the branches and were not readily located. In the diseased tissues at the base of the buds, however, and in the dead buds themselves, they were present in sufficient quantities to be clearly visible in median sections to the unaided eye.

Although the 1-year-old branches were chiefly affected, in 1951 the bacterium was also isolated from a discrete canker on the main stem of a 4-year-old tree (var. Moorpark). This canker was 5 cm. long and half girdled the stem; it gummed profusely, and in form and subsequent development resembled those on cherry caused by *Ps. mors-prunorum*.

The die-back and leaf spotting recurred in 1950 and 1951, but were generally less extensive and severe than in 1949. The shoot wilt has not been seen since 1949; in that year, however, it assumed spectacular proportions and was accounted the dominant phase of the disease. Of 284 shoots examined on five 3-year-old seedling trees, 118 had tip wilt and a further 75 the restricted lesion type of infection. Wholesale leaf abscission resulted from both types of infection and when the course of the disease was checked in June by the onset of hot, dry weather, 43·1 % of the original leaves had been lost. This defoliation resembles that recorded by Dunegan (1932) following attacks of *Xanthomonas pruni* on the shoots of stone-fruits in U.S.A., and was probably an important factor in the general devitalization of the infected trees.

Field observations and inoculation experiments suggest that Croughton is a comparatively resistant variety and Moorpark a susceptible one. There is insufficient evidence to assess the susceptibility of the other varieties affected.

INOCULATION EXPERIMENTS

The following strains of the apricot bacterium were used in inoculation experiments. The source and month and year of isolation are indicated in parenthesis. The organism was invariably re-isolated when disease symptoms followed inoculation: A1 and A15 (branches, 5/49), A9 (leaf, 5/49), A37 and A51 (shoots, 6/49), A54 and A56 (leaf, 5/50), A1*r* and A9*r* (re-isolates in May 1950 of A1 and A9, respectively, inoculated to branches the previous December), and A56*r* (re-isolate of A56 from a leaf).

Leaf spots indistinguishable from natural infections developed when strains A56 and A1*r* were pricked into leaves of apricot trees in the open. In the greenhouse A56, A51 and A1*r* were pricked into the leaves of seedling apricots with a fine needle; necroses with surrounding halos appeared after 10 days, the inoculations on the control plants remaining indiscernible. A severe necrotic spotting developed on the younger immature leaves of a seedling apricot 12 days after spraying with an aqueous suspension of A56. The control plant, sprayed with sterile water, remained unspotted.

Shoot inoculations were carried out in the spring and early summer. All the strains listed above were used, and all proved pathogenic, irrespective of their origin. Typical localized lesions consistently and rapidly followed inoculation, but great difficulty was experienced in reproducing a complete shoot wilt, even when conditions of high humidity were artificially maintained. A limited wilting was finally induced on a seedling apricot moved out of the greenhouse during relatively cold weather in June and enclosed in a glass tank for 2 days prior to inoculation.

Although die-back of the branches was not apparent until failure of the buds in spring, it was clear from the lesions then visible that infection had taken place earlier, probably, by analogy with Bacterial Canker of cherry and plum, in the preceding autumn. Branch inoculations were therefore made in December. Strains A1, A9 and A15 were used; inoculations were made with a hypodermic needle inserted tangentially under the bark, and were left uncovered.

The following spring the buds of both branches of the tree (var. Moorpark) inoculated with A1 failed to break and the branches were found to be girdled by lesions 13·0 and 7·2 cm. long respectively, resulting each from a single inoculation. The bark in these regions showed the same characteristic shiny wrinkling and brown colour observed in natural infections, and masses of bacteria were discovered in the buds.

None of the branches inoculated with A9 and A15 (var. Croughton) had die-back by May, but dark sunken elliptical lesions, from 1·2 to 4·3 cm. appeared at the site of each inoculation. Only one of these (A15) girdled. The buds on this branch had broken, but the leaves were noticeably smaller and yellower than those on the uninoculated control branches.

It will be apparent that the inoculation experiments also demonstrated the cross-infectivity of the branch, leaf and shoot isolates. The branch, leaf, and shoot infections were thus confirmed as different phases of the same disease.

THE CAUSAL ORGANISM

Of the sixty-three isolates obtained from apricot, all but two were of the same organism. This was a motile, Gram-negative, non-sporing rod, producing no gas or acid reactions from lactose, maltose or salicin incorporated in an inorganic basal medium with bromo-cresol purple as indicator. On potato plugs, growth was cream to buff with a faint purple tinge later. The above characteristics are those of *Pseudomonas* (Dowson, 1939). The green pigment typical of the genus was not produced on nutrient agar, however, but appeared consistently when the organism was grown in broth consisting of an inorganic basal medium + 1 % sodium fumarate (Erikson, 1945*a*).

On nutrient agar + 5 % sucrose, white hemispherical, radially striated colonies were formed, indistinguishable from those of *Ps. mors-prunorum* on the same medium. It further resembled this organism in the production of acid on 2 % purple lactose agar, of a milky-white growth in nutrient broth + 5 % sucrose, and by loss of viability on agar slopes of this medium within 5–6 days. These tests were regarded as important in identifying *Ps. mors-prunorum* by Wormald (1932), and especially for distinguishing it from the related stone-fruit pathogen, *Ps. prunicola*.

The similarity between the apricot organism and *Ps. mors-prunorum* was further examined by comparing their acid production on lactose, sucrose and maltose incorporated in an inorganic basal medium broth with bromo-thymol blue as indicator. The methods used were those recommended by Dowson (1949). Five strains of the apricot organism and ten strains of *Ps. mors-prunorum* (five cherry, five plum) were used. Six strains of *Ps. prunicola* (six pear, one cherry) were also included in the comparison.

Table 1

		Ps. mors-prunorum		*Ps. prunicola*		
Substrate	Apricot isolates	Cherry isolates	Plum isolates	Pear isolates	Cherry isolates	Controls
Maltose	6·5	6·6	6·5	6·7	6·2	7·0
Lactose	6·3	5·8	6·3	6·8*	6·4	7·0
Difference in final pH on maltose and lactose	+0·2	+0·8	+0·2	−0·1	−0·2	0

* Two strains produced no acid on lactose.

On sucrose, acid was rapidly produced by all strains. The acid production on maltose and lactose after 28 days is shown in Table 1. The figures refer to average final pH for each set of strains (initial pH 7·0) estimated by comparison with buffered standards. With the two exceptions noted in the table, acid was produced by all strains. *Ps. mors-prunorum* and *Ps. prunicola* could not therefore be distinguished on the basis of acid or non-acid production. The two species differed so consistently, however, in the *relative* amounts of acid produced on the two sugars, that this criterion is thought to provide a far more reliable method of distinguishing them. It will be noted that the apricot isolates agreed with *Ps. mors-prunorum* in invariably producing more acid on lactose than on maltose.

On gelatin, stab cultures of the apricot isolates caused only very slight liquefaction. This agreed with *Ps. mors-prunorum* and differed markedly from *Ps. prunicola*.

The identity of the apricot bacterium with *Ps. mors-prunorum* suggested by the cultural tests was subsequently confirmed by cross-inoculations of the apricot, cherry and plum strains into the leaves, shoots, fruits and branches of each host.

OTHER BACTERIA ASSOCIATED WITH THE DISEASE

Two isolates were obtained in successive years from dead 1-year-old branches of a mature tree (var. Bradbourne) growing in a walled garden. These resembled *Ps. prunicola* in culture, and were also pathogenic to pear and plum fruits. Their pathogenicity to apricots was not examined.

BIOLOGICAL SPECIALIZATION

Wormald (1938*a*) obtained some evidence of the biological specialization of *Ps. mors-prunorum* from cross-inoculation experiments with cherry and plum strains of the organism. With an unlimited number of strains now readily available from a third host, the apricot, this question was investigated further.

Fifteen strains (five plum, five cherry, five apricot) were isolated in mid-summer, 1950. With the exception of C6 and C7 from dead cherry spurs, these came from leaf spots. In December 1950 each strain was inoculated into branches of comparable age on each host, and the length of the resulting cankers measured the following May (Table 2).

Table 2. *Lengths of cankers (in mm.) resulting from inoculation of cherry, plum, and apricot strains of* Ps. mors-prunorum *to each of these three hosts*

(Individual strain figures are the average of five inoculations).

Strain		Host		
Type	Index no.	Cherry	Plum	Apricot
Cherry	C2	59	14	19
	C4	45	0	40
	C5	29	18	24
	C6	64	7	32
	C7	65	0	22
	Average	52·4	7·8	27·4
Plum	PU1	50	16	35
	PU2	44	25	55
	PU3	37	13	89*
	PU4	26	19	—
	PU5	21	16	31
	Average	35·6	17·8	52·5
Apricot	A57	13	10	64
	A58	21	28	37
	A59	17	28	120*
	A60	16	10	96*
	A61	21	15	46
	Average	17·6	18·2	72·6

* The lesions from the five inoculations coalesced and became continuous. The figure represents one-fifth the length of the larger lesion.

An analysis of variance was made after logarithm transformation of the data. Since the inoculations on plum were on the stem, they were not strictly comparable with those on cherry and apricot. The plum data was analysed separately therefore and in the original form.

The effect of strain types on host. There was no significant difference between the strains in the size of the lesions they produced on plum, but very highly significant differences on cherry and apricot.

The effect of host on strain types. Differences in the size of lesions on cherry and apricot were significant for each of the three strain types.

It was quite clear, therefore, that the cherry strains of *Ps. mors-prunorum* were more pathogenic to cherry than to apricot, while the converse was true of the apricot strains. The comparatively small size of the lesions resulting from the plum inoculations accorded with the experience of Erikson (1945*b*) and may account for the failure of the plum strains to show any marked specificity to this host. It was nevertheless apparent from their pathogenicity to cherry and apricot that the plum strains differed from the cherry and apricot strains.

These results demonstrate conclusively the existence of pathogenic strains and indicate a considerable degree of parasitic adaptation to the different hosts. The possibility of an even finer adaptation to varieties of the same host now merits investigation, since this may have important bearings on the problem of disease resistance. Meanwhile it is clear, that when seeking to account for apparent differences in disease intensity and varietal performance in different localities, variation and change in the pathogen are factors of considerable importance.

Discussion

Apricots appear to have been susceptible to 'die-back' in England for many years, and this may be the chief reason for the decline in their cultivation in this country (Denham, 1941). Two causes of die-back, *Stereum purpureum* and *Sclerotinia laxa* were already known. Denham and Wormald (1942) found that *S. laxa* usually invaded through the open flower as on morello cherry. Other forms of die-back, unrelated to these two fungi, have however been known for some time. Thus Cayley (1923) found *Diaporthe perniciosa* associated with this condition in apricots and other stone fruits, but was unable to produce conclusive evidence of its pathogenicity.

Much of this unexplained die-back in plum and cherry has since been shown to be caused by *Pseudomonas mors-prunorum*. It is now clear that this organism is also responsible for a die-back of apricots. With the discovery of so important a parasite on apricot, it must not be assumed however that all possible explanations of die-back are now exhausted. There is, for example, no evidence yet that *Ps. mors-prunorum* is responsible for 'Apoplexy', a term widely used to indicate a progressive die-back of mature apricots characterized by a rolling of the leaves.

The main features of the apricot bacteriosis, a summer leaf spot alternating with a winter die-back, resemble that of plum and cherry. The shoot attacks appear to be incidental to this cycle, developing only when special environmental conditions coincide with a particular stage of shoot development. On such occasions this phase of the disease may assume epidemic proportions. These conditions, low temperature, high humidity and continuous rain, probably facilitate mass infection through the stomata and arrest shoot development sufficiently to allow establishment of the disease. Similar environmental conditions are well known to be conducive to epidemic infection in other bacterial diseases, e.g. lilac blight (*Ps. syringae*).

The failure to induce shoot wilt consistently in inoculation experiments, an experience also reported by Wormald (1930) with *Ps. prunicola*, can probably be attributed to the difficulty of maintaining a suitable environment under experimental conditions.

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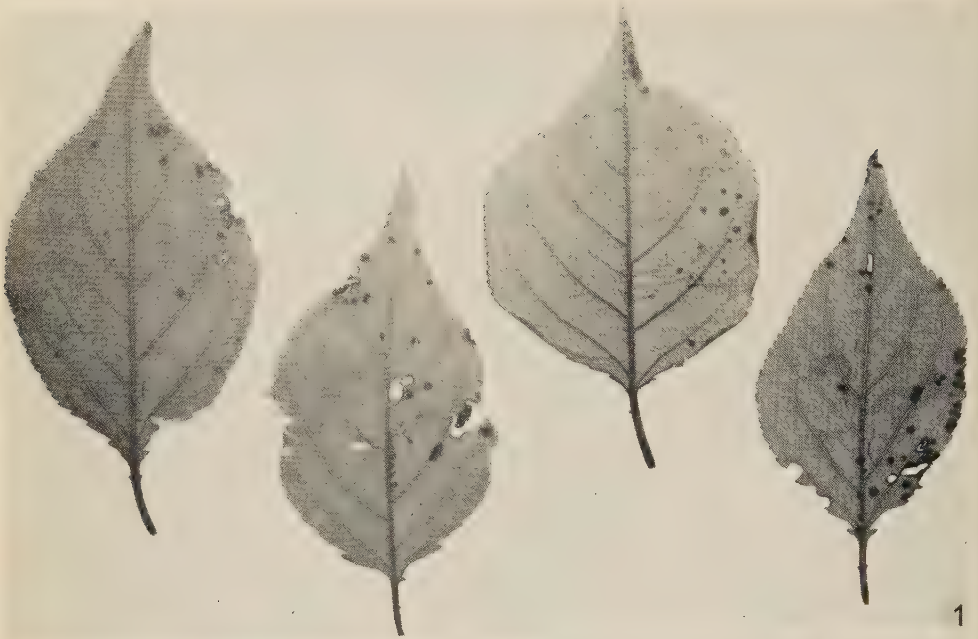
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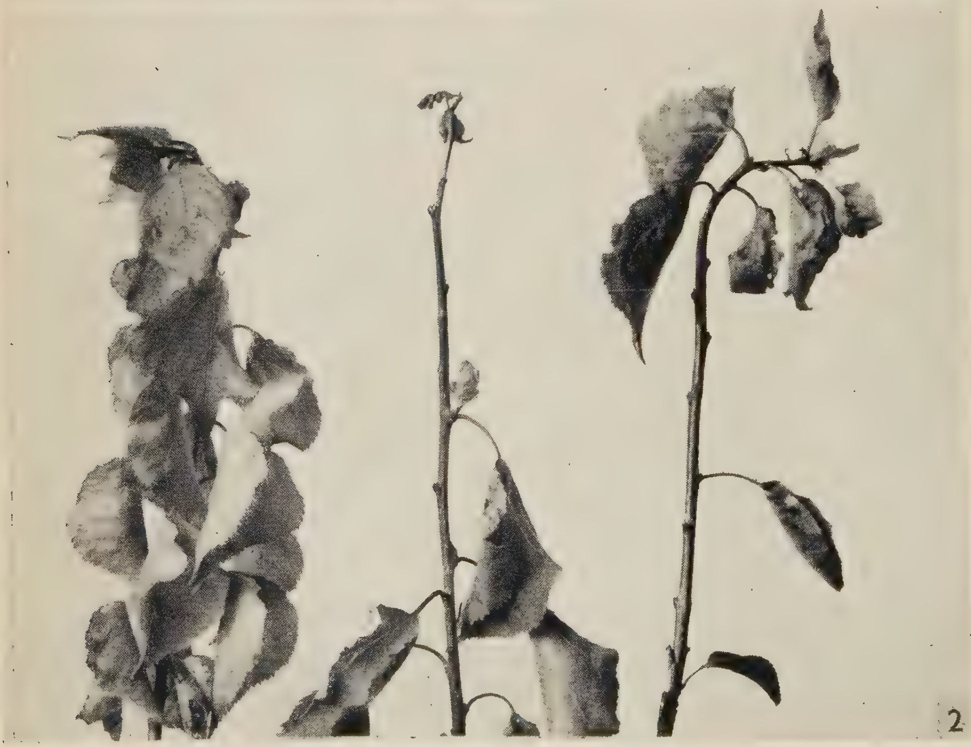
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REFERENCES

Cayley, D. M. (1923). Fungi associated with 'die-back' in stone-fruit trees. *Ann. appl. Biol.* **10**, 253–275.

Crosse, J. E. (1951). The leaf scar as an avenue of infection for the cherry Bacterial Canker organism *Pseudomonas mors-prunorum* Wormald. *Nature, Lond.*, **168**, 560–561.

Denham, H. (1941). Apricots. *J. R. hort. Soc.* **66**, 370–374.

Denham, H. & Wormald, H. (1942). The Brown Rot disease of the Apricot. *J. R. hort. Soc.* **67**, 261–263.

Dowson, W. J. (1939). On the systematic position and generic names of the Gram-negative bacterial plant pathogens. *Zbl. Bakt.* (2. Abt.), **100**, 177–193.

Dowson, W. J. (1949). *Manual of Bacterial Plant Diseases.* London: A. and C. Black.

Dunegan, J. C. (1932). The Bacterial Spot disease of the peach and other stone fruits. *Tech. Bull. U.S. Dep. Agric.* no. 273.

Erikson, D. (1945*a*). Certain aspects of resistance of plum trees to bacterial canker. I. Some biochemical characteristics of *Pseudomonas mors-prunorum* Wormald and related phytopathogenic bacteria. *Ann. appl. Biol.* **32**, 44–52.

Erikson, D. (1945*b*). On the nature of the bacterial invasion of *Prunus* sp. by *Pseudomonas mors-prunorum* Wormald. *Ann. appl. Biol.* **32**, 112–116.

Wilson, E. E. (1931). A comparison of *Pseudomonas prunicola* with a canker-producing bacterium of stone-fruit trees in California. *Phytopathology*, **21**, 1153–1161.

Wilson, E. E. (1936). Symptomatic and etiologic relations of the canker and blossom blast of *Pyrus* and the Bacterial Canker of *Prunus*. *Hilgardia*, **10**, 213–240.

Wormald, H. (1930). Bacterial diseases of stone-fruit trees in Britain. II. Bacterial Shoot Wilt of plum trees. *Ann. appl. Biol.* **17**, 725–744.

Wormald, H. (1931). Bacterial diseases of stone-fruit trees in Britain. III. The symptoms of Bacterial Canker in plum trees. *J. Pomol.* **9**, 239–256.

Wormald, H. (1932). Bacterial diseases of stone-fruit trees in Britain. IV. The organism causing Bacterial Canker of plum trees. *Trans. Brit. mycol. Soc.* **17**, 157–169.

Wormald, H. (1938*a*). Bacterial diseases of stone-fruit trees in Britain. VII. The organisms causing bacterial diseases in sweet cherries. *J. Pomol.* **16**, 280–290.

Wormald, H. (1938*b*). Two ornamental shrubs as hosts of the organism causing plum Bacterial Canker. *Rep. E. Malling Res. Sta.* 1937, pp. 198–200.

Wormald, H. (1942). Bacterial diseases of stone-fruit trees in Britain. VIII. Bacterial Canker of peach. *Trans. Brit. mycol. Soc.* **25**, 246–249.

EXPLANATION OF PLATE 1

Fig. 1. Bacterial leaf spot of apricot caused by *Pseudomonas mors-prunorum*.

Fig. 2. Shoot infections. Left, healthy; centre, 'tip wilt'; and right, shoot with localized lesions. Note severe defoliation on infected shoots.

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PRODUCTION OF SPORES BY *CERCOSPORELLA HERPOTRICHOIDES*

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(With Plate 2)

Eyespot lesions on young wheat plants in the field regularly produced conidia of *Cercosporella herpotrichoides* Fron in early spring. Conidia were not produced on mature growing plants, but after ploughing, lesions on infected straws spored freely, especially in wet weather.

In the laboratory, eyespot lesions on straws produced spores when soaked in water for 24 hr., drained and kept continuously wet. Disks 5 mm. diameter, cut from cultures on potato dextrose agar or water agar, produced spores abundantly when kept touching water at favourable temperatures, but excess water reduced sporing. Spores developed most abundantly when temperatures fluctuated between -3 and 13° C., were produced freely when temperatures fluctuated between 12 and 22° C., more slowly at 1–2° C. and were not produced at 24–25° C. Daylight did not seem to influence spore production.

Early investigators obtained only a sterile mycelium from eyespot lesions on wheat. The disease was therefore recognized many years before the causal organism was identified. Fron (1912) named the fungus *Cercosporella herpotrichoides* from spores (conidia) on infected wheat straw collected in Northern France in 1909. Foëx (1914, 1919) found the spores on young wheat plants and stubble. Foëx and Rosella (1930, 1931) isolated a fungus which produced eyespot lesions on young wheat plants, on which they occasionally found spores of *C. herpotrichoides*; as the fungus did not produce spores in pure culture, they called it 'fungus *x*'. In North America, Heald (1924) from 1919 to 1924 consistently isolated a sterile fungus from eyespot lesions in wheat. Sprague (1931) and Sprague and Fellowes (1934) obtained spores in pure culture from the fungus isolated from eyespot lesions on wheat in Oregon. They grew it in flasks on sterilized cornmeal and, after the usual hemispherical mounds had developed in the laboratory, placed the cultures outdoors in autumn, when temperatures fluctuated between $-4°$ and 16° C. After about a month, spores of *C. herpotrichoides* developed on pseudopionnotes, on coremia and on loosely formed sporodochial pads, often in slimy pink masses. They showed that this fungus caused eyespot lesions and that it was the same as Foëx's 'fungus *x*' from which they obtained similar spores. Other workers experienced difficulty in obtaining spores in culture, but in Germany, Schaffnit (1933) succeeded, using roll cultures on potato stem agar, and so did Moritz (1932) and Moritz and Bockmann (1933) on agar low in nutrients (soil and so-called hunger agar), after exposure to low and fluctuating temperatures varying from -4 to 21° C. In Holland, Oort (1936) using the latter method did not obtain spores, but did so by removing strips from roll cultures on potato stem and malt agar exposed to temperatures fluctuating from 0 to 15° C. and allowing the mycelium to grow over the glass.

During the past fourteen years spores of *C. herpotrichoides* have been regularly observed on eyespot lesions on living wheat plants and on stubble in field and pot experiments at Rothamsted, and methods have been devised which induce rapid spore production on naturally infected straw and in culture. These observations and methods, which make rapid identification possible and which have greatly facilitated study of the disease, are described here.

On plants. On young wheat plants, spores often develop before macroscopic lesions appear. They occur on the coleoptile, sometimes first at the tip; on leaf sheaths, often in axil of blade and sheath where moisture collects, much more rarely on the green blade, and abundantly on dying outer leaves and sheaths.

Winter wheat has been examined monthly in most years since 1938 on Broadbalk, and sometimes on other fields infested by eyespot. Spores were found on young wheat plants once in November, in some years in January and every year in March. Spores then became less numerous and few were found on living plants after early May. Non-sporing infected plants, collected before May and kept in damp chambers, often produced spores on eyespot lesions after a few days, plants collected later usually did not.

Young wheat plants grown in soil or sand usually produced spores in 4 to 12 weeks after they were inoculated with small pieces of culture. The time needed varied with temperature and moisture, and was reduced to 2–4 weeks by enclosing inoculated plants in an almost saturated atmosphere and spraying with water once or twice daily.

On straw. Lesions on mature living plants did not seem to produce spores but the infected bits of straw, lying on the soil after ploughing, did so abundantly in wet weather from September to April; though much less common in summer, spores have been found on wet stubble as late as July. Frost seemed to increase sporing and dry weather to decrease it; lesions on dry straws, wetted and kept damp, often produced spores.

A routine method was devised for producing spores on eyespot lesions on straws. They were soaked in water for 24 hr., drained in air for about ½ hr. (though this was not essential) and kept damp in a covered watch-glass or on wet sand or soil. Spores were sometimes produced in 2–7 days and were generally abundant in 1–3 weeks. Severe lesions on which the black dots of stromatic cells had developed, produced more spores than did superficial lesions. Sporing continued for many weeks. Some infected straws, kept outdoors and examined at intervals, bore spores from January to November; others eventually stopped producing spores of *C. herpotrichoides*, other fungi taking its place. The slightly curved linear spores of *C. herpotrichoides*, with fine tip and broader base, are easily distinguished. This method of identification is quicker and easier than culturing, which is often difficult, when rapidly growing secondary invaders, such as *Fusarium* spp. swamp the slow growing *Cercosporella herpotrichoides*. The method has often been useful for testing effects of physical factors or of chemicals on the fungus, as when Dion (1944) used it to compare effects of varying concentrations of H_2SO_4.

In culture. Standard methods for producing spores in culture, such as cutting, scraping the surface or exposing the culture to ultra-violet light, were tried without success. By contrast, disks cut with a cork borer (*e.g.* 5 mm. diameter) from cultures on potato-dextrose agar and placed on growing wheat seedlings, damp soil or sand have regularly produced spores since the method was first tried in 1939. Spores are sometimes developed within 2, and generally within 4 days, and are abundant after 1–2 weeks; profuse sporing continues for many weeks.

Attempts were made to induce similar sporing in pure culture. In earlier work, Glynne (1939) had found that some fungi isolated from wheat roots, notably *Alternaria* spp. which produced sterile cultures on potato dextrose agar, developed abundant spores round the edges of 5 mm. disks cut out from the culture, placed on sterile slides on damp filter-paper in Petri dishes and then kept in an incubator at about 22° C. Cultures of *Cercosporella herpotrichoides* treated in this way, produced no spores. A series of experiments testing modifications of the method showed, however, that spores were produced if a drop of water (0·01 ml.) was applied to disks cut from cultures on potato dextrose or on water agar, provided that the damp chambers containing them were kept in a cool glasshouse or on a window sill. Sporing was increased if the disks were placed on the under, instead of the upper, surfaces of slides supported on glass rods or on the under surfaces of Petri-dish lids, over damp filter-paper or water. When the damp chambers were kept in an incubator at about 20° C. or in the cellar, spores were either not formed or were few and developed slowly. In the glasshouse and on the laboratory window sill, spores were produced freely on the disks if placed in 1 or $1\frac{1}{2}$ in. watch-glasses with 0·5 c.c. water and kept in damp chambers, or if placed on damp sand in Petri dishes, or on inverted slides in damp chambers. Spores are sometimes formed within 4 days and are generally abundant in 2 or at most 3 weeks. They develop profusely whether or not precautions are taken against contamination of the culture disks. Spores are produced most rapidly and profusely on disks placed on exposed soil, sand or young wheat plants, sprayed or watered regularly and kept outdoors or in unheated glasshouses. They develop on widely different-sized pieces cut from old or young cultures; small pieces (1 mm. diameter) produce spores more rapidly, but ultimately less abundantly than larger ones (10 mm. diameter).

Cultures on potato-dextrose agar are dark and opaque, so it is difficult to see spores *in situ*, except at the edge of the disk, but they readily fall into the surrounding water. Cultures on water agar are transparent and spores are easily seen, often first near the edge, later developing over the whole surface. The numbers that developed on the two media were compared in tests in the unheated glasshouse. Disks were removed from the under surfaces of inverted slides in damp chambers and each dipped in a separate drop of 0·01 ml. sterile water, which was then examined; the numbers of spores in a microscopic field 1·5 mm. diameter in the part of the drop where they were most abundant were recorded. After 1 week six disks on water agar gave 0, 8, 50, 25, 45, 250 spores and six disks on potato-dextrose 30, 3, 7, 0, 0, 20; after 2 weeks, taking the disks in the same order, numbers on water agar were 25, 0, 130, 100, 300, 400 and on potato dextrose 1500, 160, 300, 600, 100, 100. All disks were sporing after 3 weeks; spores reached maximum numbers in 2 weeks, remained high till the 5th week, then declined; spores still occurred after 7 weeks.

Factors controlling spore production. A low nutrient level seems to favour spore production as spores develop on small pieces but not on whole cultures: they are produced more rapidly on water agar than on the richer potato dextrose agar, and develop most freely under conditions which inhibit mycelial growth.

Contact with water for some time after cutting the disks seems necessary for spore production; small differences in moisture have large effects; water condensing on disks on the under surfaces of slides on Petri-dish lids (keeping them wetter than disks placed in water drops on upright slides, where they tend to evaporate), produced conditions favourable to spore production. Disks touching water near the rim of watch-glasses spored more freely than those in the middle; excess water thus reduced spore production; submerged disks did not spore. The best moisture conditions seemed to be provided when disks, on soil, sand or young wheat plants were watered periodically and so exposed to alternate wetting, draining and even drying. In a series of tests in darkened and clear-glass damp chambers spores developed as rapidly and freely on disks kept in darkness as in those exposed to daylight. A typical test on the effect of temperature is shown in Table 1, which gives the temperature range in different sites and the maximum and minimum number of spores on five similarly treated disks. For each treatment five disks cut from a culture on potato-dextrose agar were placed: (*a*) on inverted slides in damp chambers;

Table 1. *Spore production in sites with different temperature ranges*

(Range in number of spores on five disks after 12, 19 and 28 days.)

Site and temperature range (° C.)	Days	(*a*) Inverted slide	(*b*) Watch-glass	(*c*) Wet sand
Glasshouse unheated, −3 to +13	12	50–1000	12–150	100–1000
	19	1000–2000	150–1600	1500–2500
	28	1200–5000	200–5000	2500–5000
Laboratory window sill, 11–18	12	15–500	100–700	0–400
	19	60–750	45–200	30–400
	28	100–200	100–200	60–100
Glasshouse heated, 12–22	12	60–160	5–500	8–150
	19	60–250	60–500	40–250
	28	150–250	30–120	30–100
Cold room, 1–2	12	0–5	0–50	0–3
	19	60–300	30–300	3–25
	28	120–2000	60–300	4–400
Incubator, 12–16	12	4–50	0–12	0–10
	19	8–200	3–25	5–30
	28	7–500	4–12	3–7
Constant temperature room, 24–25	12	0	0	0
	19	0	0	0
	28	0	0	0

(*a*) On inverted slides in damp chambers. (*b*) In watch-glasses with 0·5 c.c. water in damp chambers. (*c*) On wet sand in 2 in. Petri dishes.

(*b*) in watch-glasses with 0·5 c.c. water in damp chambers; (*c*) on wet sand in Petri dishes, all previously sterilized. Moisture changes depending on temperature, though most likely to occur in (*a*), were apparently negligible, because the damp chambers were kept very wet by adding water when necessary during the test. After 12 days spores had developed on all disks in the two glasshouses and on the laboratory window sill, on eleven and twelve respectively of the fifteen disks in the incubator at 12–16° C. and in the cold room at 1–2° C. After 19 days spores had developed on all disks except those at 24–25° C., which even after 28 days produced no spores. Spores developed most profusely where temperatures fluctuated from -3 to 13° C.; they developed fairly abundantly where temperatures fluctuated from 11 to 18° C. and from 12 to 22° C. At 1–2° C. spores were few at first, but after 28 days were fairly abundant. A parallel series of disks cut from cultures on water agar produced spores but in smaller numbers than those on potato dextrose, and at 24–25° C., no spores were produced.

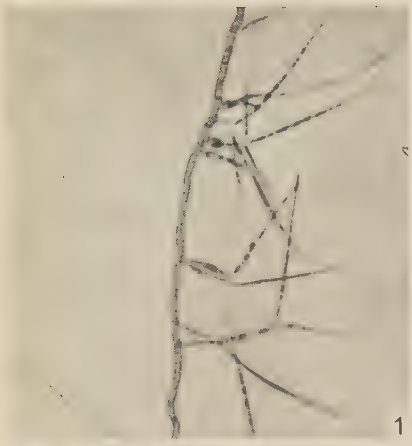
The existence of strains of *C. herpotrichoides* with different sporing capacity was shown in a comparison of four isolates, one of which from oats and one from rye spored more profusely than two from wheat. In cultures on potato-dextrose agar the isolate from oats grew most rapidly, and that from rye least rapidly.

Germinating spores. When many spores are produced on young wheat plants, on straw or on culture disks, they do not seem to germinate in the surrounding water. But when such a suspension is diluted in a drop of water and kept at room temperature for 24 hr. the spores germinate, sometimes at both ends, and in 48 hr. have about doubled their length. In distilled water they often bud off a new crop of spores in about a week. On a drop of potato-dextrose agar the mycelium from germinating spores grows vigorously over the surface of the glass and produces groups of parenchymatous cells on which spores are produced less rapidly but more profusely than in distilled water.

Modes of spore formation. Two methods of spore production, sometimes merging into one another, are common. In the first method spores are budded from the mycelium, or from short, slim or swollen conidiophores (Pl. 2, figs. 1–3). In the second method groups of more or less oval cells develop and form a substrate on which many spores are produced (Pl. 2, figs. 4–6). The first is the quicker method and is often the first stage in spore production on young plants; it occurs on mycelium growing out over glass from disks or from spores in distilled water. The second method occurs later on young plants; on dying outer leaves, on eyespot lesions on straw, on the edges of disks of potato-dextrose agar, and from spores growing on a drop of this medium. On water agar, clusters of spores develop at short intervals along the mycelium. The pink masses of spores which Sprague (1931) found on cornmeal were not found in my experiments, using other media.

Spores vary much in length, shorter spores tending to develop under conditions unfavourable to spore production.

Dispersal of spores. In an attempt to detach spores from eyespot lesions on straws, dry air from an atomizer was puffed at them, after a greased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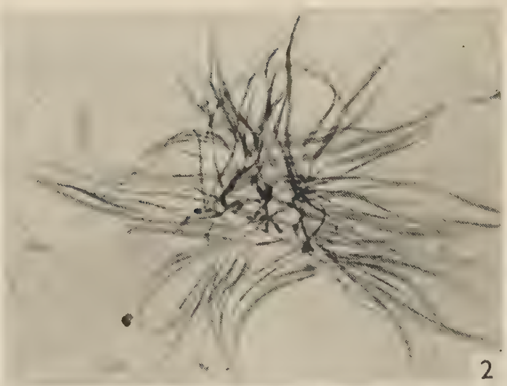
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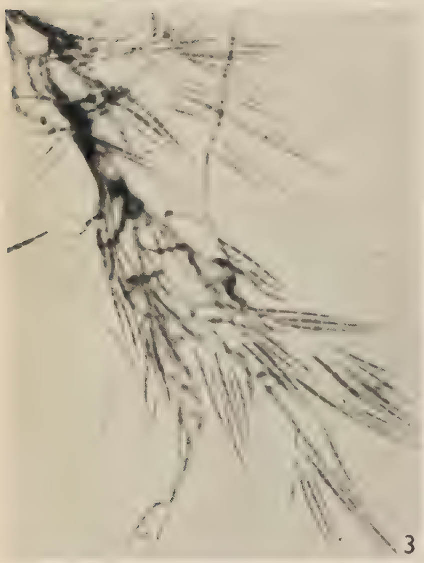
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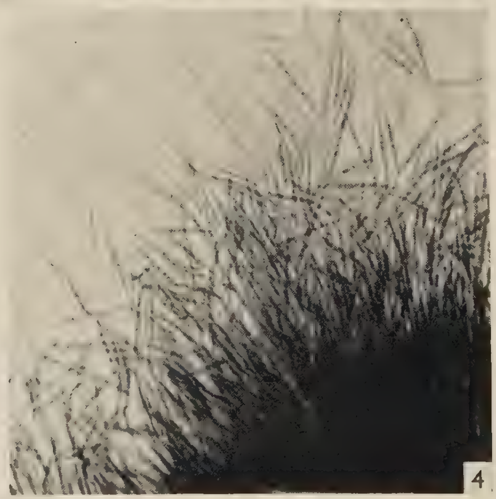
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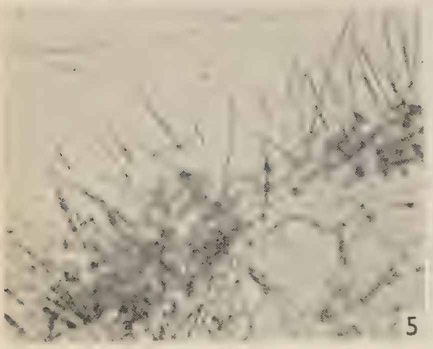
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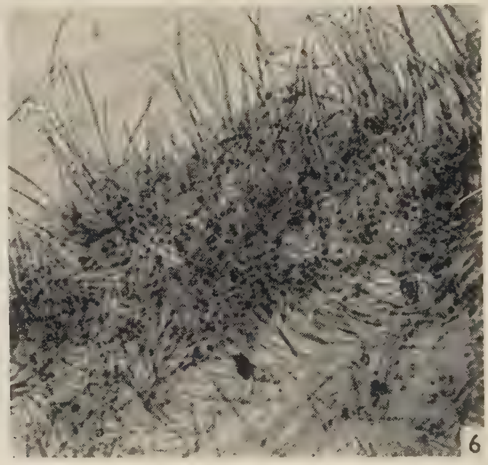
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slide had been placed 2 in. away in a position to catch detached spores. None was caught, but when a fine mist was substituted for dry air and a dry for a greased slide, many spores were caught in mist droplets on the slide. Splashes from drops of water falling from 12 ft. on to sporing straws also carried spores, which were caught at a height of 2 ft. in the splash drops. In the field, spores are probably dispersed by rain, splash droplets carrying spores and often being blown considerable distances.

The part played by spores in pot experiments using culture disks as inoculum was suggested in an experiment, in which disks were placed on young wheat plants kept damp by watering from above, and on others kept wet by standing the pots in saucers of water. Those watered from above became much more severely infected than those watered through the saucers. In another test, culture disks were pinned to the surface of soil 1 in. away from a surrounding circle of wheat seedlings, sprayed regularly with water. All developed eyespot lesions, splashed spores being the only source of infection. Both outdoors and in the glasshouse, screens, placed to catch splashed drops, have proved effective in protecting uninoculated plants from infection carried from neighbouring inoculated pots; when screens are not used, uninoculated plants become heavily infected.

REFERENCES

Dion, Wendy M. (1944). Factors affecting the incidence of *Cercosporella herpotrichoides* Fron causing eyespot of wheat. Ph.D. Thesis, University of London, pp. 1–65.

Foëx, E. (1914). Quelques faits relatifs au piétin du blé. *Bull. Soc. Path. vég. Fr.* **1**, 26–30.

Foëx, E. (1919). Note sur le piétin du blé. *Bull. Soc. Path. vèg. Fr.* **6**, 52–56.

Foëx, E. & Rosella, E. (1930). Sur les diverses formes du piétin. *Rev. Path. vég.* **17**, 41–51.

Foëx, E. & Rosella, E. (1931). Recherches sur le piétin. *Ann. Épiphyties*, **16**, 51–82.

Fron, M. G. (1912). Contribution à l'étude de la maladie 'pied noir des céréals' ou 'maladie du piétin'. *Ann. Sci. agron., Paris*, **4**, 3–29.

Glynne, Mary D. (1939). Fungal invasion of the roots of healthy wheat plants. *Trans. Brit. mycol. Soc.* **23**, 210.

Heald, F. D. (1924). 1920–24. Investigations needed. Footrot of wheat. *Bull. Wash. Sta. agric. Exp. Sta.* (1920) **155**, 38; (1922) **167**, 39–40; (1922) **175**, 36; (1924) **187**, 71.

Moritz, O. (1932). Die Fusskrankheiten des Weizens. *Mitt. dtsch. LandwGes.* **47**, 957–958.

Moritz, O. & Bockmann, H. (1933). Einleitende Studien über *Cercosporella herpotrichoides* Fron. *Angew. Bot.* **15**, 409–419.

Oort, A. J. P. (1936). De oogvlekkenziekte van de granen veroorzaakt door *Cercosporella herpotrichoides* Fron. *Tijdschr. PlZiekt.* **42**, 179–234.

Schaffnit, E. (1933). *Cercosporella herpotrichoides* Fron als Ursache der Halmbruchkrankheit des Getreides. *Phytopath. Z.* **5**, 493–503.

Sprague, R. (1931). *Cercosporella herpotrichoides* Fron, the cause of the Columbia Basin footrot of winter wheat. *Science*, **74**, 51–53.

Sprague, R. & Fellowes, H. (1934). Cercosporella footrot of winter cereals. *Tech. Bull. U.S. Dep. Agric.* no. 428, 1–24.

EXPLANATION OF PLATE 2

Figs. 1–3. Spores of *Cercosporella herpotrichoides* Fron on mycelium growing out over glass from disk culture. × approx. 500.

Fig. 4. Spores growing from edge of disk of potato-dextrose agar. × approx. 500.

Figs. 5, 6. Spores on leaf sheath of young wheat plant. × approx. 500.

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A NEW SPECIES OF *ENTOMOPHTHORA* ON BEETLES

By S. K. BOSE and P. R. MEHTA

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(With 11 Text-figures)

During July 1950, a severe mortality of chestnut defoliating beetles (*Brahmina* sp.) was noticed at the Government Gardens, Chaubattia, India. The insects were found to be affected with an undescribed species of *Entomophthora*. The internal hyphae were profuse, hyaline and branched, giving external digitate conidiophores, bearing ovoid papillate conidia measuring 18–22 × 11–15 μ. The zygospores were internal, spherical, measuring 22–39 μ in diameter, and characterized by thick-walled, spiny, adherent epispore. Haustoria were disk-like, lobed with fine papillae on the under-surface. The fungus has been designated as *E. brahminae* Bose et Mehta n.sp.

During July 1950, a large number of chestnut defoliating beetles (*Brahmina* sp.) were found dead on the leaves of chestnut trees in the Government Gardens, Chaubattia (altitude 7000 ft.), Uttar Pradesh, India. The beetles were firmly attached to the leaf surface by their mouthparts, and anchored by strands of hyphae arising from the ventral side. Since only a few entomogenous fungi have been recorded from India, and in view of the beneficial nature of the fungus which was causing heavy mortality of the defoliating beetles of chestnut, the fungus was investigated in greater detail.

MORPHOLOGY OF THE FUNGUS

Microscopic examination showed that at first the beetles were infected with numerous colourless, unseptate, branched hyphae, ramifying in the various internal organs of the body. These usually measure 7–9 μ in width. A few hyphae are up to 16 μ in width. Later, the hyphae by coiling form thick strands, which ultimately replace most of the tissues beneath the integument (Fig. 1), culminating in the death of the beetles. The latter, before death, crawl up on the leaves and branches of the chestnut plants and die, firmly clinging to the substratum by their mouthparts. After the death of the beetle a number of thick hyphae emerge from the interior and grow down towards the surface of the leaf or branch. These hyphae are 14–24 μ in width. On touching the substratum, the apical part of each hypha expands into a flat saucer-like radiating lobed structure, measuring 100–160 μ in diameter. The under-surface of these anchoring disks is beset with fine papillae, by means of which they are firmly attached to the substratum. The formation of haustoria is favoured by moist weather, and they are strong enough to keep the insects anchored during heavy rains which are frequent in these parts (Figs. 2 and 3).

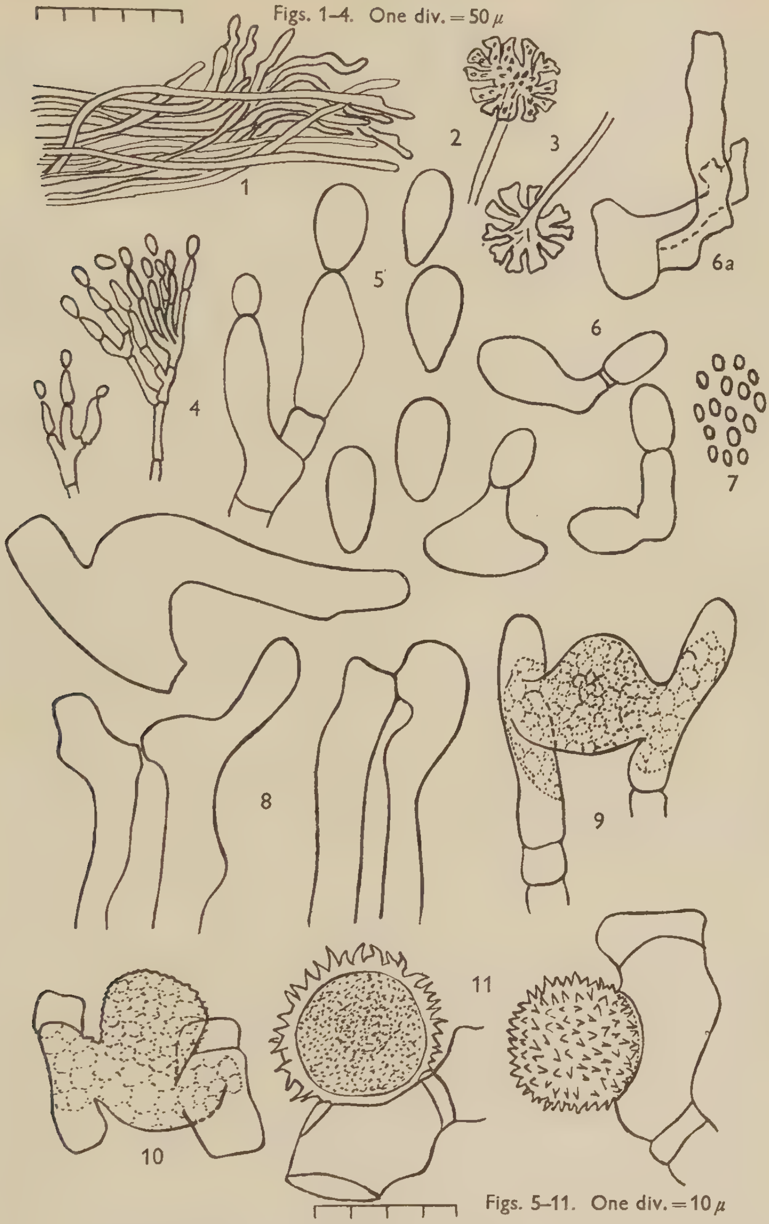

Fig. 1. Hyphae within the host coiling into strands.
Fig. 2. Disk-like, lobed haustorium, showing papillae on the lower surface.
Fig. 3. Haustorium showing smooth upper surface of the lobed disk.
Fig. 4. Conidiophores.
Fig. 5. Conidia.
Fig. 6. Formation of secondary conidia.
Fig. 6*a*. Formation of germ tube from primary conidium.
Fig. 7. Small oval spores produced by the longer germ tubes.
Fig. 8. Copulating branches and fused hyphal body.
Figs. 9–10. Beginning of zygospore formation.
Fig. 11. Mature zygospore.

During moist weather a number of hyphae emerge beneath the thorax and the abdomen, become septate, and branch profusely into a dense tuft of short hyphae. The apical segments elongate into mammillate, bluntly pointed sterigmata, measuring 14–39 × 8–9 μ. These swell at the apex into a globose structure, which is finally cut off by a cross-wall as an ovoid conidium, measuring 18–22 × 11–15 μ (Figs. 4 and 5).

Conidial germination in tap water takes place readily within 12 hours. Usually a short hyphal projection emerges from the side or the apex, and this swells up at its tip into a secondary conidium, similar in shape and size to the one from which it was produced. A few conidia were observed to send out one or two long, branched, septate or unseptate hyphae. In water the latter cut off small, oval spores, measuring 4–7 μ in diameter (Figs. 6 and 6*a*). These also germinate by means of a germ tube (Fig. 7).

Resting spores are formed within the insect at the same time as the conidia. The hyphae fuse laterally or apically. These copulating parts break up into U-, H-, or h-shaped pieces depending upon the mode of fusion (Fig. 8). The fused area broadens, and the content of the conjugating pieces accumulates there. In advanced stages the interior of the dead insect becomes full of such hyphal pieces, replacing the vegetative hyphal strands. The apical part of the broad fused area bulges, and the content of the hyphal piece passes into this bulge. The latter becomes spherical, thick-walled and spiny. The mature resting spores are hyaline or light yellowish, and measure 22–39 μ, with an average of 29 μ in diameter. A portion of the conjugating pieces usually remains attached at the base of the resting spore (Figs. 9–11).

Besides *Brahmina* sp. a single apple defoliating beetle (*Anomela rufiventris* Redt.) was also found clinging to a weed beneath a chestnut plant. Examination of this insect showed it to be affected with a fungus identical in all respects with that on *Brahmina* sp.

IDENTITY OF THE FUNGUS

The fungus belongs to the family Entomophthoraceae. The nature of the reproductive structures, especially the branched nature of the conidiophores, is characteristic of the genus *Entomophthora*. A perusal of literature showed that no species with echinulate zygospores is known on beetles. Since the fungus appeared to be new, specimens were sent to the Commonwealth Mycological Institute, Kew, England, for confirmation. The fungus was examined by Dr M. B. Ellis who reported that no species of *Entomophthora* like this appeared to have been described on beetles. However, the authors were advised by Dr Ellis and Mr E. W. Mason to compare the fungus with *E. echinospora* Thaxter in view of its close morphological similarity. The authors unfortunately did not have access to authentic specimens of *E. echinospora*, but from the published descriptions of the fungus (Engler & Prantl, 1897; Thaxter, 1888), it appears that the fungus on beetles resembles the former in some respects. The echinulate character of the zygospores and the dimensions of the reproductive bodies are similar. However, it was found that the two fungi are not identical. They are compared in Table 1.

Table 1

E. echinospora	*Entomophthora* sp. on chestnut beetle
Conidiophores digitate, coalescing into a mat-like covering, which turns rust coloured upon exposure	Conidiophores digitate, never forming a mat. No rust colour is formed upon exposure
Conidia ovoid, tapering to a papillate base, 20–25 × 10–14 μ	Conidia ovoid, tapering to a papillate base, 18–22 × 11–15 μ
Secondary conidia like primary	Secondary conidia like primary. In addition, small oval conidia (4–7 μ in diameter) are formed from longer germ tubes
Resting spores, zygospores, spherical, 30–40 μ in diameter. Produced internally as well as externally	Resting spores, zygospores, spherical, 22–39 μ in diameter, produced internally
Zygospores always with a short neck at the base, and sometimes produced at a distance from the fused area	Zygospores never with a neck, and formed by the direct bulging out of the wall of the fused area
Epispore thin-walled and spiny, and can be removed from the spherical resting spore by pressure	Epispore thick-walled and spiny. Cannot be separated by pressure
Haustoria elongated and lobed	Haustoria disk-like, lobed, with fine papillae on the under-side

The characters of the zygospores of the two species under comparison clearly indicate that the fungus on chestnut beetle is different from *E. echinospora*. The internal sessile zygospores of the fungus on beetles, with their firm thick spiny wall, and their mode of formation are quite distinct from the zygospores of *E. echinospora*. The conidiophores of the two fungi are also different. It is therefore proposed to name the fungus on *Brahmina* sp.

Entomophthora brahminae Bose et Mehta sp.nov.

Conidia ovoidea, ut plurimum desinentia in basim papillatum, 18–22 × 11–15 μ. Conidiophori ramosi, externi, desinentes ad apicem in sterigmata mammillata, hebete acuta, 14–39 × 8–9 μ. Conidia secundaria similia primariis vel tenuiter diversa. Longiores germinationis tubuli producuntur in aqua in 5 casibus %; haud raro hi tubuli parvulas sporas ovoideas, 4–7 μ diam., secant; sporae vero germinant statim, nulla interposita mora, uno producto germinationis tubulo. Zygospore directe efformantur ex tumescentia quae oritur ex conjugantibus hyphae fragmentis litteria U, h, vel H similibus. Zygosporae maturae sunt sphaericae, crasso atque spinoso episporio ornatae, hyalinae vel pallide luteae, 22–39 μ (medietate 29 μ) in diam. Reliqua hypharum fragmenta semper remanent associata zygosporis. Episporium spinosum haud separari potest compressione. Zygosporae semper efformantur in interioribus partibus hospitis *Brahminae*; hospes vero permanet substrato fixus rhizoideis planis, disco similibus, 100–160 μ in diam., formatis ed apices hypharum quae extus crescunt; hae vero hyphae sunt 14–24 μ latae.

Inficit insecta generis *Brahminae*, quae defoliant *castaneas*; inficit etiam Anomelam rufiventrem Redt. defoliatricem *Pyri mali* Linn.

Habitat in 'Chestnut Block', Government Gardens, Chaubattia (Altit. 7000 ped.) in districto Almora, in regione Uttar Pradesh, India.

Parts of the type collection have been deposited in the Herbaria of the Indian Agricultural Research Institute, New Delhi, and the Commonwealth Mycological Institute, Kew, Surrey, England.

Grateful thanks are due to Mr E. W. Mason and Dr M. B. Ellis for their valuable help during the course of this investigation, and to Rev. Father Dr H. Santapau, Head of the Department of Botany, St Xavier's College, Bombay, for the Latin rendering of the diagnosis. The authors are indebted to Mr Z. A. Siddiqi, Entomologist, Government Valley Fruit Research Station, Jeolikote, Naini Tal, U.P., for the specimens of *Brahmina* sp. infected with the entomogenous fungus.

REFERENCES

ENGLER, A. & PRANTL, K. (1897). *Die naturlichen Pflanzenfamilien*, **1**, pt. 1, p. 140.

THAXTER, R. (1888). The Entomophthoraceae of the United States. *Mem. Boston Soc. nat. Hist.* **4**, 180–181.

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A NEW ASCOSPORIC SPECIES OF *ASPERGILLUS*

By EDWARD YUILL, *Acomb, York*

(With Plate 3 and 3 Text-figures)

Aspergillus quadricinctus n.sp. is related to the *A. fischeri* series of the *A. fumigatus* group. It has been isolated on two occasions from cardboard made from salvage material. Its chief distinguishing feature is the structure of its ascospores which have four membranous bands or girdles, whereas those of its nearest allies have two bands only.

In 1945, an examination of the mould flora of samples of cardboard made from salvage material showed that ascosporic species of the *Aspergillus fumigatus* group were frequently present. Several isolates had ascospores with the two equatorial bands or frills described for the *A. fischeri* Wehmer series (Thom & Raper, 1945). The perithecia were pale buff in colour. Later, a colony was noticed which had pinkish buff perithecia and ascospores which differed from those of the *A. fischeri* series in having four distinct bands instead of two. This mould was subcultured at intervals for some 12 months, but, as the production of perithecia was always sparse and erratic, a search was made from the same cardboard source for another strain without these disadvantages.

A second colony with pinkish buff perithecia and four-banded ascospores was soon found and isolated in pure culture. It was at once apparent that the second isolation produced perithecia with great freedom. No change in this respect has taken place during the 6 years it has been kept in culture.

A culture of the second isolation was sent to Dr K. B. Raper of the Northern Regional Research Laboratory, U.S.A., in 1947. He kindly examined the mould and gave his opinion that it should be described as a new species. Major H. A. Dade of the Commonwealth Mycological Institute, Kew, also examined the mould and considered that on the analogy of Thom and Raper's treatment of the *A. glaucus* and *A. nidulans* groups a specific distinction would be a sound one. It is therefore proposed to name it *Aspergillus quadricinctus* n.sp. and I am indebted to Major Dade for suggesting the specific epithet.

Aspergillus quadricinctus sp.nov.

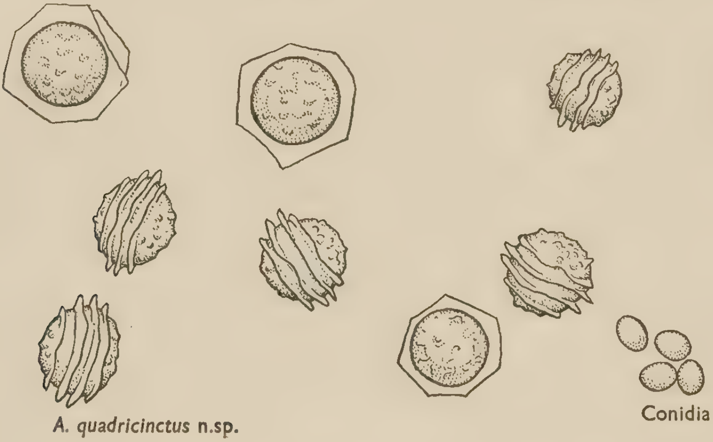
Coloniae in agaro, 'malt' dicto, valide crescentes, perithecia in stratis pluribus plerumque, capitula conidiorum pro ratione rara sparsaque efformantes, raro floccosae, sed in sectoribus frequenter funiculosae. *Capitula conidiorum* pallido-veneta, quam illa *A. fumigati* minus columnaria, ab illis *A. fischeri* difficile distinguenda. *Perithecia* roseo-bubalina, globosa, usque ad 300 μ diam., plerumque hyphis pausis sterilibus circumdata. *Asci* plerumque subglobosi, 8-spori, 10–12 × 8–10 μ. *Ascosporae* hyalinae, saepe spinulosae vel reticulatae, e frontae circulares, 5 μ diam., cinctis 6- ad 8-angulatis circumdatae, in toto 6·5 μ diam.; e latere ovales, 5 μ longae, 4 μ latae, sulcis carentes, cinctis linearibus quaternis, illis interioribus excelsioribus, circumdatae.

Ex charta 'cardboard' dicta, York, Angliae, 1946, isolatus et culturus.

A dried culture grown on malt agar, which has been deposited in the herbarium of the Commonwealth Mycological Institute, Kew, is designated as the type.

Cultures have also been deposited at the Commonwealth Mycological Institute and at the Northern Regional Research Laboratory, Peoria, U.S.A.

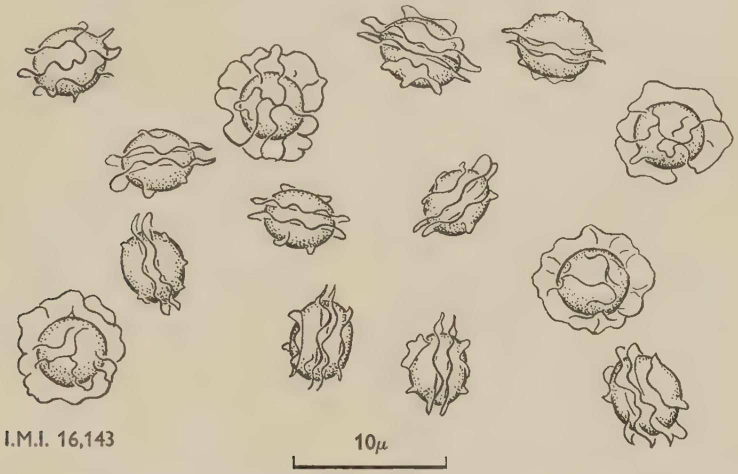
Inoculations on malt agar from perithecia grow rapidly at temperatures from 23 to 28° C., becoming predominantly perithecial with conidial heads few and scattered. Floccose aerial mycelium is uncommon, though sectors showing fasciculate hyphae occur frequently. On Czapek agar with 30 % sucrose the mycelium is densely floccose, with conidiophores freely produced from aerial hyphae. Perithecia develop beneath the aerial mycelium but not in such large numbers as on malt agar. On malt agar with 20 % sucrose, perithecia are rarely produced. Colonies are often entirely conidial and aerial mycelium completely absent. *Perithecia*, produced in several layers, generally surrounded by only a few sterile hyphae, typically pinkish buff; globose, up to 300 μ in diameter. *Asci* mainly subglobose, 8–10 by 10–12 μ, each containing eight ascospores. *Ascospores* colourless, ascospore body 5 × 4 μ with two prominent equatorial bands, each duplicated by a somewhat less prominent band. In plan view the bands appear as roughly regular polygons of six to eight sides. They are exceedingly thin and average 1·3 μ in width. The ascospore valves are often spinulose or reticulate. *Conidial heads* loosely columnar, very variable, light blue-green in colour, 50 × 130 μ, less commonly as much as 70 × 180 μ. *Conidiophores* smooth, colourless or pale blue-green towards the vesicle, up to 400 μ high, 2–7 μ in diameter, often septate, broadening to the flask-shaped vesicle which has a diameter of from 10 to 20 μ. *Sterigmata* 7 × 2 μ wide, formed on the upper half of the vesicle in one series. *Conidia* elliptical to globose, mainly 2–3 μ in diameter, smooth.



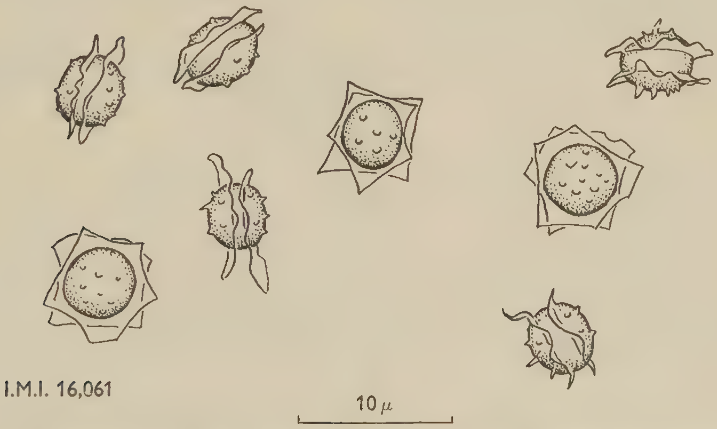
Text-fig. 1. Ascospores and conidia of *A. quadricinctus* n.sp. × 2200.

Conidial heads which develop from aerial hyphae are usually very short stalked and smaller than those arising from submerged mycelium.

Colony characteristics alone would not suffice for the identification of *A. quadricinctus*. It is the form of the ascospores which marks it off from other species of the *A. fumigatus* group.



Text-fig. 2. I.M.I. 16,143, an isolation from soil which has ascospores with anastomosing frills on the valves, characteristic of *A. fischeri* Weh.



Text-fig. 3. Ascospores of I.M.I. 16,061 isolated from hay. These have equatorial frills, but only small tubercles on the valves, and this culture thus seems similar to Lindt's *A. malignus*, under which name it is disposed at the Commonwealth Mycological Institute.

It is of interest to note that one or other of the chief characteristics of *A. quadricinctus* has its parallel in other species of the *A. fumigatus* group and in species of the less closely related *A. nidulans* group. The most striking parallel is found in Thom and Raper's *A. quadrilineatus*, a species belonging to the latter group. Here, the ascospores, like those of *A. quadricinctus*, have four bands. They take the form of narrow ridges rather than membranous appendages. The most important group containing ascosporic species—

the *A. glaucus* group—does not provide any close parallels, although the ascospores are of the same general type as in the *A. fumigatus* and *A. nidulans* groups. It does show, however, certain similarities in the ascospores of its species with those of the new mould's closest allies, *A. fischeri* and *A. malignus*. The formation of frills on the ascospore valves as well as equatorial bands in *A. fischeri*, and the smaller outgrowths on the valves in *A. malignus*, seem to be variations and developments of the similar type of ornamentation of the valves in *A. amstelodami* (*A. glaucus* group). Another species, *A. chevalieri*, has ascospores with equatorial bands which correspond, essentially, with those of *A. fischeri* and *A. malignus*. *A. fischeri* has ascospores with anastomosing frills without an angular outline, but often shows a tendency to form parallel extra frills. In *A. malignus* the ascospores have two frills only and these show an angular outline very similar to the outline of the bands observed in *A. quadricinctus*. An extreme case of angularity of outline is found in *A. variecolor* (*A. nidulans* group). The two prominent equatorial crests, up to 3·5 μ in width, are so cut that they give the ascospore a distinctive stellate appearance.

These, and other parallels which might be mentioned, between species in different *Aspergillus* groups, make it fairly clear that the various characteristics dealt with are *generic* tendencies.

I am much indebted to Major H. A. Dade for many helpful suggestions, for providing cultures of species in the *A. fumigatus* group and for preparing the text-figures, of which Text-figs. 2 and 3 are from Major Dade's own originals. Thanks are due to Mr E. W. Mason for translating the diagnosis into Latin, and to Messrs John and E. Sturge Ltd., Birmingham, for permission to publish.

REFERENCE

Thom, C. & Raper, K. B. (1945). *A Manual of the Aspergilli*, p. 151. London.

EXPLANATION OF PLATE 3

Fig. 1. *Aspergillus quadricinctus* n.sp. Conidial heads. × 260.
Fig. 2. *A. quadricinctus* n.sp. Colony on malt agar—almost entirely perithecial.
Fig. 3. *A. quadricinctus* n.sp. Ascospores. × 960.
Fig. 4. *A. quadricinctus* n.sp. Ascospores. × 1200.

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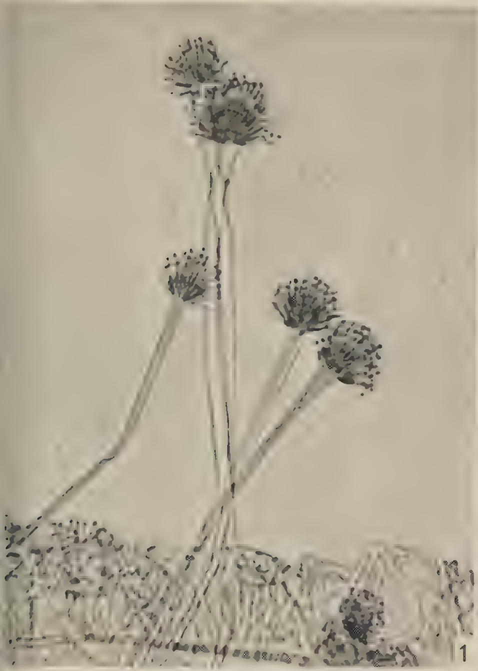
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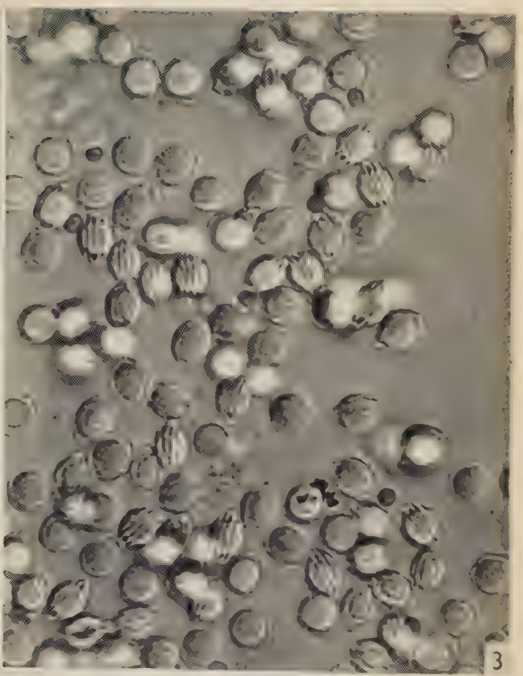
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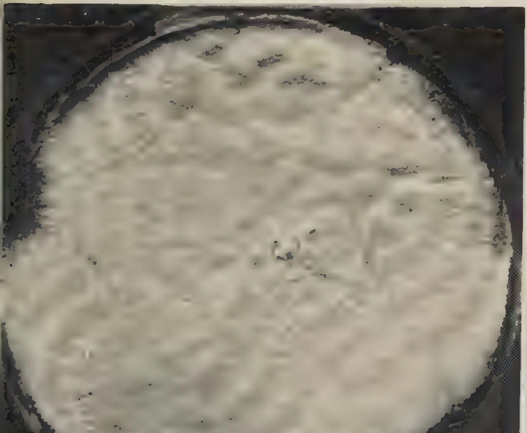
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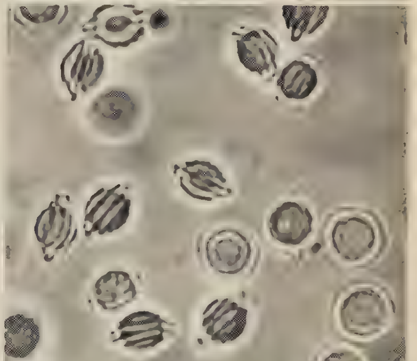
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FOOT ROT OF FLAX CAUSED BY *ASCOCHYTA LINICOLA*

By ALLEN KERR

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(With Plate 4 and 1 Text-figure)

The disease known in Britain as foot rot of flax is described and shown to be caused by *Ascochyta linicola* Naoumoff & Vassilievsky.

A similar disease occurs in Denmark, Germany and Czechoslovakia where it is attributed to *Phoma lini* Pass., and in New Zealand where it is attributed to a species of *Phoma*. *P. exigua* Desm. is shown to be very similar to *Ascochyta linicola* Naoum. & Vass. *Phoma herbarum* West. is shown to be distinct from *Ascochyta linicola* Naoum. & Vass. A non-pathogenic species of *Phoma* isolated from flax is described.

During the 1939–45 war, when the acreage of flax grown was greatly increased, foot rot proved serious in some districts of Britain. The disease was very prevalent in Scotland, Wales and in the English counties of Somerset and Dorset (Keay, 1948). It soon became apparent that much confusion existed about the identity of the causal fungus. Species of *Phoma* and *Ascochyta* have been recorded on flax from Russia, Germany, Belgium, Holland, Latvia, Estonia, Spain, France, Denmark, Czechoslovakia, Australia and New Zealand, as well as from the British Isles. The species have been variously referred to as *Phoma linicola* Bubák, *P. linicola* Naoumoff, *P. linicola* Marchal & Verplancke, *P. lini* Pass., *P. exigua* Desm., *P. herbarum* West., *Ascochyta linicola* Naoumoff & Vass. and *A. usitatissima* Rothers.

The first description of *Phoma linicola* was given by Bubák (1914). This fungus occurred on old stems of *Linum mucronatum* in Mesopotamia, and was not associated with a foot rot. The name foot rot was first proposed for a disease of flax caused by a species of *Phoma*, recorded from Ireland by Pethybridge, Lafferty and Rhynehart (1921). They gave no particulars of the causal fungus. A similar disease was reported from Belgium by Marchal and Verplancke (1926). The chief symptom was severe rotting of the base of the stem, so that the young infected plants soon died. The fungus associated with the Belgian disease was assumed to be identical with that causing foot rot in Ireland, and was named *P. linicola* Marchal & Verplancke. The same year Naoumoff (1926) independently described a species of *Phoma* from Russia which he called *P. linicola*. This fungus formed isolated, subepidermal pycnidia on the middle and apical portions of the stem. The infected stems were not killed or discoloured. In naming these fungi, Marchal & Verplancke and Naoumoff were, apparently, unaware of Bubák's previous publication.

Naoumoff also described *Ascochyta linicola*, which formed brown pycnidia densely crowded at the base of the stems. It caused a brown discoloration which gradually extended far beyond the region occupied by the pycnidia. Diddens (1929) referred to a herbarium of flax fungi distributed by Jaczewski, containing specimens and a description of *A. linicola* Naoumoff & Vassilievsky, and she isolated the fungus from this material. From a careful study of it, both on flax and in culture, she concluded that a disease of flax in Holland, similar to that described by Naoumoff, was caused by *A. linicola*. *A. linicola* was recorded from Latvia by Eglits (1929) and from Russia by Rothers (1927), who also recorded a new species, *A. usitatissima*, which formed gregarious pycnidia on the apical portions of flax stems. *A. linicola* was recorded from France by Grente (1948), who stated that it was responsible for the disease 'mort-lin'. A species of *Ascochyta* quite distinct from the fungus causing foot rot has been recorded from Northern Ireland and investigated by Muskett and Colhoun (1947). A description of this fungus has not yet been published.

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Phoma lini Pass. was first described by Passerini (1890) on the stems of *Linum tenuifolium* near Parma in Northern Italy. The pycnidia were scattered and the spores were somewhat curved. Rost (1938) reported *Phoma lini* Pass. as common in Germany. He stated that the fungus was found on seedlings and on fully grown flax stems from ground-level up to a height of 10 cm. It formed a dense pycnidial colony. A species closely resembling *P. lini* Pass., but with smaller pycnidia, was reported by Johansen (1943) from Denmark to cause exceptionally severe damage to the Canadian spinning flax variety, J.W.S. Navratilova (1949) recorded *P. lini* as one of the fungi causing foot rot ('Usychani Lnu') in the border districts of Bohemia and Moravia. 'A few weeks before the plants develop seeds the bases of the stalks gradually become brown and are eventually covered with black dots to a height of 10 cm. The bark separates from the wood, the fibres are torn in several places and the cortex becomes loose.'

Rudiger (1948) recorded *P. lini* as causing browning and drying of the leaves and breaking of the stems at the base. The disease is known in Germany as Pustelkrankheit.

P. exigua Desm. was first described in two forms: '(*a*) Peritheciis rotundatis occurrit in foliis *Polygoni tatarici*. (*b*) Minor; peritheciis saepe ovatis, occurrit in foliis Ranunculorum' (Desmazières, 1849). More recently, it has been recorded on flax from Russia (Kletschetow, 1924), France (Marchal & Foëx, 1927), Spain (Unamuno, 1930), Estonia (Lepik, 1931), and Holland (De Jonge, 1933). From Denmark, Johansen (1943) recorded *Phoma exigua* on young linseed plants on which it produced 'olive-green, later light-brown, irregular sharply delimited lesions on the leaves and cotyledons and reddish-brown stripes on the root collar'. Navratilova (1949) recorded *P. exigua* in association with foot rot. Pycnidia were formed in groups on lesions.

Phoma herbarum West. in Westendorp's Exsiccati No. 965 is 'sur les tiges de l'ortie et du sainfoin'. 'Ortie' is stinging-nettle and the fungus was listed under *Urtica* in the 1854 list (Westendorp, 1854). *Phoma herbarum* was reported as a parasite of flax by Kirchner (1905). Van Poeteren (1929) found *P. herbarum* associated with the so-called red disease of flax in the Zierikzee district of Zeeland.

There are many records of unidentified species of *Phoma* on flax. Gentner (1923) stated that *Phoma* sp. and *Botrytis cinerea* were frequently observed on Bavarian flax seed. Millikan (1944) recorded a species of *Phoma* from Victoria, Australia, which produced a severe spotting of the stems in a few plants of the Concurrent variety of flax. The bases of the affected plants usually appeared quite normal. A species of *Phoma* was recorded in the 1943–4 survey of flax crops in New Zealand. It was associated with a canker near the base of flax stems.

MATERIAL AND METHODS

For this investigation specimens of species of *Phoma* and *Ascochyta* which have been recorded on flax were obtained from as many sources as possible. The specimens studied are listed in Table 1. Wherever possible, the fungi were obtained in culture. Malt agar (2½ % malt extract, 2½ % agar) was used as a culture medium unless stated otherwise. Sections were cut of many of these specimens. The material was fixed in formalin-acetic acid, dehydrated with N-butyl alcohol and finally embedded in paraffin wax with a melting-point of 135–140° F. Sections were stained with Bismarck brown.

Table 1. *Sources of material used in the investigation*

Species	Recorded in literature by	Country	Sender
Phoma linicola	Marchal & Verplancke (1926)	Belgium	Jacques, M. C. Férange
Ascochyta linicola	Naoumoff (1932)	Russia	W. C. Moore
A. linicola (3 strains)	Diddens (1929)	Holland	Prof. Westerdijk
A. linicola (3 strains)	Grente (1948)	France	Prof. Limasset
Phoma lini Pass.	Johansen (1943)	Denmark	Prof. Buchwald
P. exigua Desm.	Desmazières (1849)	France	Director, Kew Gardens
P. herbarum West.	Westendorp (1854)	Belgium	Director, Kew Gardens
Phoma sp.	—	Germany	Prof. Eglitis
Phoma sp.	N.Z. flax survey	N. Zealand	Director, D.S.I.R., N.Z.
Phoma sp.	—	Scotland	Dr Mary Noble

When measuring pycnidia and spores twenty measurements were made in every case.

Millikan did not have specimens of the *Phoma* sp. recorded by him on flax from Victoria, Australia, but specimens of flax infected with foot rot were sent to him for examination.

FOOT ROT OF FLAX IN SCOTLAND

(i) *Source of infection.* It was at first thought that the most important method of infection was from the soil (Naoumova, 1932). A survey of the disease was carried out in 1944 and 1945 by the Plant Pathology Service of the Department of Agriculture for Scotland and the Scottish Advisory Mycologists. This survey showed that the relative health of the seed was the most important factor in the spread of the disease. While seed-borne infection is the main source of disease, outbreaks may result from sowing healthy seed in infected soil. Soil may be readily infected artificially in the laboratory by placing on the soil small pieces of inoculum obtained from a pure culture of the fungus (see Pethybridge *et al.* 1921).

(ii) *Symptoms of disease.* Seedlings grown from infected seed or growing in infected soil are attacked in the pre-emergence stage or shortly after brairding. The hypocotyls are attacked at ground-level, infected seedlings wilt and soon fall over and die. Diagnosis of the disease on seedlings is difficult, although pycnidia may develop when infected seedlings are placed on moist filter-paper in a Petri dish. The symptoms of foot rot at this stage closely resemble the symptoms of infection with *Colletotrichum linicola* Pethybridge & Laff. Pl. 4, fig. 1, shows a cotyledon of an infected seedling.

The first obvious symptom of infection on more mature plants is wilting and shrivelling of the lower leaves. On diseased plants an area, involving approximately 8–10 cm. at the base of the stem, becomes discoloured, is at first dark green in colour, but quickly becomes yellow or brown. At this stage, many pycnidia are present on the discoloured area (Pl. 4, fig. 2). The fungus is present in the cortex, the cells of which are completely disorganized (Pl. 4, fig. 3). Very often the cortical tissues, which bear the pycnidia, peel away from the woody tissues. Although it is usual to find the pycnidia confined to the base of the stem, discoloured areas bearing pycnidia are sometimes found higher up the stem, as well as on the sepals and walls of the capsules. Mycelium is sometimes found in the outer layers of the seed coat and pycnidia occasionally occur on the surface of the seed. Infected seeds are not easily distinguished from healthy seeds. If the seeds are germinated in a moist atmosphere, pycnidia readily develop on the seed coats.

(iii) *Description of foot rot fungus.* The pycnidia are densely crowded, dark brown in colour, and usually have one, but occasionally two, ostioles. The pycnidia are thin-walled, subepidermal, and each consists of a single chamber. The majority of the spores are unicellular, elliptical, hyaline, typically biguttulate; a small percentage (1–5 %) is uniseptate. Measurements of pycnidia and spores of the fungus from infected flax stems were:

Pycnidia = 164 × 135 μ (100–320 × 77–300).
Spores (1-celled) = 6·6 × 3·1 μ (5·0–8·6 × 2·6–3·9).
Spores (2-celled) = 10·8 × 3·6 μ (8·7–11·0 × 3·3–4·2).

There is considerable variation in size of pycnidia on different infected stems. A more accurate representation was obtained by measuring a few pycnidia from many stems than by measuring many pycnidia from one stem.

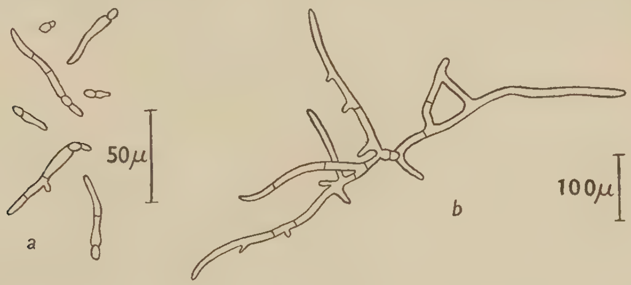
The measurements of pycnidia as they occurred on two separate stems were:

Stem (1) Pycnidia = 142 × 123 μ (107–174 × 77–162).
Stem (2) Pycnidia = 175 × 139 μ (109–320 × 90–300).

In the present investigation, germination of spores was studied by means of Kniep's agar film technique, as modified by Sass (1929). Long cover-slips were used instead of microscope slides. By this method, germination was studied under high and low powers of the microscope.

The agar film was inoculated with a spore suspension. Spores increased to more than double their original size before they germinated. After about 12 hr. incubation at 26° C., they sent out two germ tubes in succession. Cross-walls were formed at an early stage of hyphal growth and anastomosis occurred (Text-fig. 1).

A second species of *Phoma* was frequently isolated from samples of flax grown in Britain and from flax seed. This fungus was isolated from the apical portions of flax stems, from the pedicels, from the sepals, from the walls of the capsules, and from the seed itself. The host tissue on which the fungus occurred was not discoloured. Pycnidia of this fungus have never been observed by the writer in nature. Dr M. Noble supplied material for examination. The measurements were:



Text-fig. 1. Early (*a*) and later (*b*) stages of germination of spores of the foot-rot fungus.

Pycnidia = 99 × 86 μ (57–137 × 57–124).

Seedlings growing in a Petri dish were sprayed with a spore suspension of this fungus. No apparent damage was caused but superficial pycnidia were formed at the extremities of the roots. The measurements were:

Pycnidia = 99 × 79 μ (20–148 × 20–130).
Spores = 6·4 × 3·6 μ (4·4–7·9 × 3·0–4·1).

No septate spores were observed.

Inoculation tests have also been made on more mature plants. Spore suspensions and small pieces of an agar culture of the fungus were used to inoculate the plants, some of which were wounded. No symptoms of infection appeared on the inoculated plants.

In culture on malt agar, the fungus grew rapidly at 26° C. Two days after inoculation the whole culture was covered with numerous brown pycnidia. There was very little aerial mycelium produced (Pl. 4, fig. 5). Spores were discharged from the pycnidia and the culture took on a salmon-pink appearance. On this medium, pycnidial and spore measurements were:

Pycnidia = 152 × 126 μ (115–119 × 75–165).
Spores = 6·5 × 3·6 μ (4·6–8·3 × 2·1–4·3).

No septate spores were observed.

Ascochyta linicola Naoum. & Vass.

Specimens from the herbarium distributed by Jaczewski were obtained from Mr W. C. Moore. The measurements of the fungus were:

Pycnidia = 145 × 125 μ (118–172 × 99–153).
Spores (1-celled) = 6·5–2·7 μ (5·1–8·4 × 2·4–3·2).
Spores (2-celled) = 9·9 × 3·2 μ (8–11·5 × 2·9–3·6).

In this material only 1–2 % of the spores were septate.

The original measurements given for this fungus were:

Pycnidia = 110–160 μ in diameter.
Spores (1-celled) = 5–7 × 2·5 μ.
Spores (2-celled) = up to 11 × 2·6 μ.

The specimens examined were similar in all respects to specimens of foot rot of flax.

Cultures of the three strains of *A. linicola* used by Diddens in her work on this problem were obtained from the Centraalbureau voor Schimmelcultures, Baarn. Three strains of *A. linicola* were also obtained from France. These cultures were compared with the fungus causing foot rot.

The cultures will be referred to as:

A. Isolated by the writer from flax plants infected with foot rot. This fungus has been isolated from infected plants grown in many parts of Great Britain and also from seed from Northern Ireland.
B. Isolated by Diddens from flax from Zeeland. (b/w.)
C. Isolated by Diddens from Jaczewski's herbarium specimens. (Rus.)
D. Isolated by Diddens from flax, most probably attacked by the Dutch disease 'dode harrel'. (Harrel.)
E–G. Isolated from flax grown in France (strains 1–3).

In culture, all the isolates had a similar habit of growth.

Isolate A. The mycelium developed as a mat of loose white aerial hyphae, growing to a height of 3 mm. After 3 days, the aerial mycelium turned dirty grey in colour. The submerged hyphae darkened and the substrate at the centre of the culture became dark olive-green. This colour soon spread over the culture, leaving a narrow margin of about 3 mm. where the submerged hyphae were clear. The margin of the culture became irregular and crenate (Pl. 1, fig. 6*a*). After about 8 days, black hyphal knots (pycnidial rudiments) appeared in the submerged growth. Only a few pycnidia matured. The culture was about 4 cm. in diameter after 7 days. The fungus also grew well on potato-dextrose agar and oat agar. Growth on malt agar and on potato-dextrose agar was very similar. On oat agar the dark coloration in the substrate did not appear until 4 or 5 days after inoculation. The aerial mycelium remained much whiter and the crenation of the margin was not so marked.

Isolate B was similar to isolate A except that growth was slower (Pl. 4, fig. 6*b*) and that mature pycnidia were not formed.

Isolate C produced a dense grey aerial mat of mycelia which obscured the dark coloration of the substrate (Pl. 4, fig. 6*c*). This aerial mat was much less dense in cultures grown in diffused daylight, than in those kept in the dark (Pl. 4, fig. 6*d*).

Isolate D grew faster in culture than isolates A–C, and the crenation of the margin was not so marked. Pycnidia were not produced by isolates C and D.

Isolate E was very similar to isolate A.

Isolates F and G had typical crenate margins but little aerial mycelia and numerous pycnidia were produced.

The pathogenicity of isolates A–D was tested on a range of hosts. The pathogenicity of isolates E–G was tested on flax.

Table 2

Isolate	A	B	C	D	E	F	G	Control
No. of healthy seedlings after 8 days	0	0	3	10	2	16	14	18
	0	2	3	6	2	14	14	17
	0	1	5	7	1	15	14	18
Total	0	3	11	23	5	45	42	53

Flax. Twenty-four tumblers were filled with partially sterilized soil. Twenty-one of the tumblers were inoculated with isolates A–G (one isolate to three tumblers) by placing pieces of malt-agar culture on the surface of the soil. In the remaining three tumblers sterile malt agar was used instead of agar cultures. Twenty seeds of the linseed variety Redwing (the only variety available which was free from seedborne infection) were sown in each tumbler and covered with partially sterilized soil. Table 2 shows the number of healthy seedlings 8 days after sowing. Isolates A–E were re-isolated from infected seedlings which were washed several times in sterile water and plated on malt agar. Pycnidia were produced on the seedlings infected by isolates A, B and E. The measurements of pycnidia and spores produced by isolate B were:

Pycnidia = 133 × 116 μ (96–161 × 75–142).
Spores = 5·7 × 2·7 μ (4·62–7·11 × 2·24–3·54).

No septate spores were observed. On re-isolating this fungus from infected seedlings a culture was formed in which numerous pycnidia were produced. A small percentage of the spores from these pycnidia were septate.

Potato. Inoculations were made on tubers of the variety Majestic, using the method described by Dennis (1946). A piece of an agar culture was inserted into a small cut made on the surface of the washed tuber which was placed on damp *Sphagnum* moss under a bell-jar. Isolates A–D were each inoculated into eight tubers (two inoculations to one tuber) and, as controls, eight tubers were inoculated with sterile agar. The inoculated tubers were kept at room temperature (about 15° C.). All isolates produced a small, more or less circular, hard brown rot, 1–1·5 cm. diameter. Growth ceased in a few weeks. There was no rotting in the control tubers. Pycnidia were not produced on the lesions. At the end of the experiment, the isolates were successfully re-isolated.

Tomato. Green tomato fruits were inoculated by the method described for potato tubers.

Isolate A. A circular sunken lesion with white aerial mycelia was produced. The diameter of the lesion was about 1·5 cm. 14 days after inoculation and 2·5 cm. after 28 days. As the fruit ripened a soft rot developed. This was usually associated with secondary infection by *Mucor* spp. Two of the controls developed a soft rot due to secondary infection, but fourteen remained hard and firm, showing only a slight drying out of the tissues where inoculation had been made. Pycnidia were produced in profusion (Pl. 4, fig. 4).

Isolate B. The type of rot produced by isolate B was similar to that produced by isolate A but only immature pycnidia were formed.

Isolate C produced a lesion which was more superficial and which had a wide black margin.

Isolate D produced a slower rot. The appearance of the lesion was similar to that produced by isolate C.

Pycnidia were not produced by isolates C and D.

Phoma linicola Marchal & Verplancke

Herbarium specimens of *P. linicola* Marchal & Verplancke from Belgium were examined microscopically. Measurements of the fungus were:

Pycnidia = 156 × 141 μ (97–232 × 83–227).
Spores (1-celled) = 6·5 × 2·9 μ (5·2–8·2 × 2·4–3·4).
Spores (2-celled) = 8·6 × 3·1 μ (7·7–10·1 × 2·6–3·7).

Less than 1 % of the spores was septate. Pycnidia were present at the base of the stem, and in appearance the Belgian material closely resembled foot rot. The measurements of spores did not agree with those given by Marchal & Verplancke.

The original measurements given for this fungus were:

Pycnidia = 110–180 μ in diameter.
Spores = 8·5–13 × 4·3–8·5 μ.

The fungus could not be obtained in culture.

Phoma linicola Naoumoff

Specimens of *P. linicola* Naoumoff could not be obtained. The original measurements given for this fungus were:

Pycnidia = 150 μ in diameter.
Spores = 10–13·4 × 3·3–5 μ.

Phoma lini Pass.

Type specimens of *P. lini* Pass., or of *P. lini* Pass. as described by Rost, could not be obtained. Specimens of the fungus closely resembling *P. lini* Pass. but with smaller pycnidia, recorded by Johansen (1943), were examined. Measurements of pycnidia and spores of this fungus agreed with those of the foot-rot fungus, and the general appearance of the disease resembled foot rot. The measurements were:

Pycnidia = 152 × 138 μ (100–180 × 90–165).
Spores (1-celled) = 6·3 × 2·9 μ (4·9–8·0 × 2·5–3·6).
Spores (2-celled) = 10·8 × 3·5 μ (8·5–11·2 × 2·9–3·9).

Specimens of *P. lini* recorded by Navratilova (1949) and Rudiger (1948) could not be obtained.

PHOMA EXIGUA DESM.

Type specimens of *P. exigua* Desm. were obtained from the Director, Royal Botanic Gardens, Kew.

P. exigua Desm. (Crypt. France, Ser. 1, 1869, on *Polygonum tataricium*). Pycnidia densely crowded formed grey patches on the substrate, subepidermal, 130 × 120 μ (100–150 × 95–137), ostiolate, black to the eye, brown with thin parenchymatous wall when soaked up and mounted, spores elliptical, straight or slightly curved 6·4 × 2·9 μ (4·4–9·5 × 2·5–3·5), a few 1-septate 8·8 × 3·1 μ (7·0–10·8 × 2·6–3·7).

Phoma exigua Desm. is very similar to the fungus causing foot rot of flax. The pycnidia of *P. exigua* are more spherical and slightly smaller than those of the foot-rot fungus. Otherwise the two fungi cannot be distinguished morphologically.

Specimens of *P. exigua* described by Johansen (1943) and Navratilova (1949) could not be obtained.

PHOMA HERBARUM WEST.

Type specimens of *P. herbarum* West. were obtained from the Director, Royal Botanic Gardens, Kew.

P. herbarum West. (Westendorp Exs. No. 965 on *Urtica*). Pycnidia scattered, 237 × 165 μ (177–279 × 130–177), ostiolate but not beaked, subepidermal, black to the eye, brown with thin parenchymatous wall when soaked up and mounted, spores elliptic-cylindrical 4·5 × 1·75 μ (4–5·5 × 1·5–2). No septate spores were observed.

Phoma herbarum West. is quite distinct from the fungus causing foot rot of flax. Pycnidia and spores of *P. herbarum* are easily distinguishable from those of the foot rot fungus.

PHOMA SPP.

Specimens of flax attacked by foot rot were sent to C. R. Millikan in Victoria. In a communication Millikan stated that in his opinion the fungus causing foot rot in Scotland differed from that recorded by him on flax in Victoria.

A specimen of the species of *Phoma* recorded from New Zealand was examined by the writer.

The measurements of the fungus were:

Pycnidia = 191 × 163 μ (119–250 × 110–221).
Spores (1-celled) = 6·5 × 3·1 μ (4·4–7·0 × 2·6–3·4).
Spores (2-celled) = 9·3 × 3·5 μ (9·0–11·0 × 3·1–4·0).

The specimens resembled foot rot both morphologically and anatomically. The pycnidia formed a dense colony at the base of the stem, the cortical tissues tended to peel away from the wood and the cells of the cortex were disorganized.

Specimens of flax infected with a fungus similar to that causing foot rot were obtained from Germany. Measurements of pycnidia and spores were:

Pycnidia = 158 × 130 μ (108–205 × 92–191).
Spores (1-celled) = 6·6 × 3·0 μ (5·3–8·3 × 2·7–3·6).
Spores (2-celled) = 10·5 × 3·2 μ (8·7–11·1 × 3·0–3·6).

The fungus was obtained in culture and grown on malt agar. Cultures of the fungus were indistinguishable from cultures of the foot-rot fungus.

DISCUSSION

A review of the literature has shown that there is much confusion about the identification of the species of *Phoma* and related genera which occur on flax. In the British Isles, however, the position is not so complicated. Three fungi in the group have been isolated from flax grown in the British Isles:

(1) The fungus which causes foot rot.
(2) A species of *Phoma* which is non-pathogenic and which has been isolated from the apical regions of flax and from flax seed.
(3) A species of *Ascochyta* which was recorded by Muskett and Colhoun, but which has not yet been described.

Muskett and Colhoun (1947) state that 'In the experience of the writers . . . the unnamed sp. of *Phoma* isolated from various sources in these Islands and used in the Northern Ireland investigations is the organism responsible for the disease (*foot rot*) in every case which has come to their notice.' In the course of the present work the isolate A referred to in this paper has always been isolated from infected stems which showed symptoms of foot rot.

From a study of the material in Jaczewski's herbarium, and from a comparison of the three isolates with which Diddens worked and isolate A, there can be no doubt that the fungus described by Naoumoff (1926) and named *Ascochyta linicola* Naoum. & Vass. is identical with the fungus which causes foot rot in this country. This agrees with the opinion of Dennis (1946) that two isolates which he made from flax stems suffering from foot rot 'should be placed in *Ascochyta* or *Diplodina* and seem to agree best with the description of *Ascochyta linicola* Naoum. & Vass.'. Moore (1948) and Keay (1948), who have both studied the material in Jaczewski's herbarium, also believe that the two fungi are identical. Grente (1948) has stated that the flax disease called 'mort-lin' in France is caused by *A. linicola*. The present work confirms this statement. One of the strains of *A. linicola* sent to the writer from France was similar to isolate A in all respects. The other two isolates differed slightly from isolate A in culture and were apparently non-pathogenic. This could be explained by the effect of prolonged culture on artificial media.

In appearance, the specimens of *Phoma linicola* Marchal & Verplancke, which were examined in the course of this work, resembled foot rot. The measurements of pycnidia and spores of the two fungi also agree. The spores of the Belgian fungus, however, are much smaller than the original measurements given by Marchal and Verplancke. As the fungus has not been obtained in culture it is impossible to say that this fungus is identical with *Ascochyta linicola*.

The name *Phoma linicola* Marchal & Verplancke cannot in any case be adopted for this flax foot rot fungus as it is a later homonym of *P. linicola* Bubák.

P. linicola Naoum. was described originally as being non-pathogenic to flax, and for this reason cannot be considered synonymous with *P. linicola* Marchal & Verplancke, nor can it be the cause of foot rot. It appears to be very similar to the non-parasitic *Phoma* isolated in the course of this work from the seed and apical regions of flax stems, but the size of pycnidia and spores of the two fungi do not agree. At present there is not enough information to give a specific name to the non-pathogenic *Phoma*.

The specimens of the fungus closely resembling *P. lini* Pass. received from Denmark and the specimens received from Germany were in the opinion of the writer identical with foot-rot specimens. Prof. D. Eglitis, Max-Planck-Institut für Bastfasserforschung, who supplied the German specimens, was not prepared to say that the fungus was the same as that described by Rost. Measurements of pycnidia and spores given by Rost for *P. lini* and the symptoms of the disease on flax are identical with those of *Ascochyta linicola*. The description and illustrations of *Phoma lini* by Navratilova agree with those of *Ascochyta linicola* and the symptoms of 'Usychani Lnu' are the same as the symptoms of foot rot. *Die Pustelkrankheit*, as described by Rudiger (1948), is similar to foot rot. It is very probable that *Phoma lini* as described by Rost and recorded by Johansen, Navratilova and Rudiger and *Ascochyta linicola* are synonymous.

From the literature, *Phoma lini* described by Passerini differs markedly from *P. lini* Pass. reported by Rost from Germany. According to Passerini the pycnidia are scattered, occur on the stems of *Linum tenuifolium* and are often formed in long rows, whereas according to Rost the pycnidia form a dense pycnidial colony and occur on the stems of *L. usitatissimum* from ground-level to a height of 10 cm. Passerini's description of *Phoma lini* was given before the disease foot rot was known, and there is insufficient evidence to identify the fungus which causes foot rot with *P. lini* Pass.

P. exigua Desm. is very similar morphologically to *Ascochyta linicola* Naoum. & Vass. Although the tendency to-day is to return to a morphological basis for species, it would seem desirable to reject a fungus, described on *Polygonum*, as a parasite of flax until that fungus has been re-collected on *Polygonum* and its pathogenicity tested. In recording *Ascochyta linicola* from France, Grente states 'this fungus is entirely new to France and possibly attacks previously attributed to *Phoma exigua* were really due to this species, especially as the spores of *Ascochyta linicola* in the early stages are similar to those of *Phoma exigua*'. *P. herbarum* West. is quite distinct from *Ascochyta linicola* Naoum. & Vass. The *Phoma* species recorded from New Zealand appears to be identical with *Ascochyta linicola*, although only morphological and anatomical characters were compared. The view of Millikan has already been given that the fungus recorded by him from Victoria is not the same as specimens of foot rot which he received from Britain. It would appear that 'mort-lin' in France, 'dodeharrel' in Holland, 'Usychani Lnu' in Czechoslovakia, 'Pustelkrankheit' in Germany and 'foot rot' in the British Isles are the same disease. According to Navratilova, 'Verdrekte kopfe', 'Hengeldurre' and 'Kalterbrand' are further German synonyms.

It is debatable whether the foot rot fungus should be placed in the genus *Ascochyta*. Only once during this investigation have specimens been found with 5 % of the spores septate. In all other material the number of septate spores has been about 1 %. Moore (1948) states 'Nor is the fungus a typical *Ascochyta* in other respects, and it should be referred to *Phoma* or, if the few one-celled spores are regarded as significant, to *Diplodina*.' The distinction between *Phoma* and *Phyllosticta* and between *Ascochyta* and *Diplodina* has, however, always been a matter for dispute. Moreover, it has been shown by Brooks & Searle (1921) that the number of septate spores within a species is not constant. In order not to confuse matters further, it would seem advisable to retain the name *Ascochyta linicola* Naoum. & Vass. for the fungus causing foot rot.

My thanks are due to Dr Malcolm Wilson, under whose supervision some of the work was carried out, to Dr Mary Noble, for her interest and many helpful suggestions, and to those persons who supplied material for examination.

REFERENCES

BROOKS, F. T. & SEARLE, G. O. (1921). An investigation of some tomato diseases. *Trans. Brit. mycol. Soc.* **7**, 173–197.

BUBÁK, F. (1914). *Ann. naturh. (Mus.) Hofmus., Wien*, **28**, 203. (Saccardo, *Syll.* **25**, 104, 1931.)

DE JONGE, L. J. A. (1933). Plantenziektenkundige vraagstukken in verband met de Vlascultuur. *Tijdschr. PlZiekt.* **39**, 1–10. (Abstr. in *Rev. appl. Mycol.* **12**, 372.)

DENNIS, R. W. G. (1946). Notes on some British fungi ascribed to *Phoma* and related genera. *Trans. Brit. mycol. Soc.* **29**, 11–42.

DESMAZIÈRES (1849). *Ann. Sci. nat.*, Ser. 3, **11**, 282.

DIDDENS, H. (1929). De Ascochyta-ziekte van het Vlas. *Tijdschr. PlZiekt.* **35**, 251–253. (Abstr. in *Rev. appl. Mycol.* **9**, 112.)

EGLITS, M. (1929). Some diseases of flax and flax seed disinfection experiments. *Rep. Latvian Inst. Plant Protect.* 1928–9. (Abstr. in *Rev. appl. Mycol.* **9**, 246.)

GENTNER, G. (1923). Bayerische Leinsaaten. *Faserforschung*, **3**, 277–300. (Abstr. in *Rev. appl. Mycol.* **3**, 273–274.)

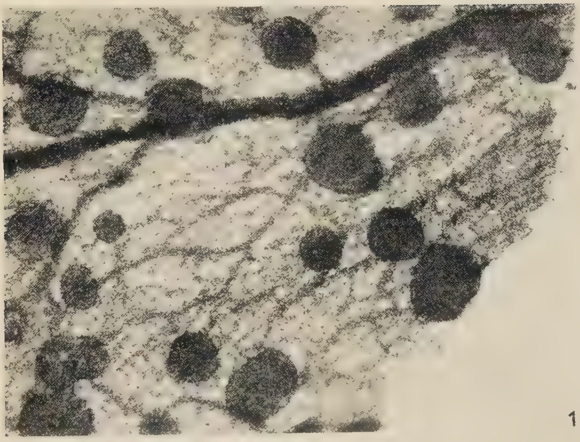
GRENTE, J. (1948). Influence des attaques de mort-lin sur le rendement du Lin cultivé. I. Influence sur le rendement en fibres. *Ann. Epiphyt*, N.S., **14**, 27–37. (Abstr. in *Rev. appl. Mycol.* **28**, 396.)

JOHANSEN, G. (1943). Hørsygdomme. *Tidsskr. Planteavl.* **48**, 187–298. (Abstr. in *Rev. appl. Mycol.* **24**, 450.)

KEAY, M. A. (1948). 'Fungal Diseases of Flax.' Unpublished Ministry of Supply Report.

KIRCHNER, O. (1905). *Krankheiten und Beschädigungen unserer landwirtschaftlichen Culturpflanzen.* Stuttgart.

KLETSCHETOW, A. N. (1924). Untersuchungen über die biologischen Ursachen der Leinmüdigkeit des Bodens. *J. landw. Wiss., Mosk.*, **1**, 511–521. (Abstr. in *Rev. appl. Mycol.* **5**, 100.)



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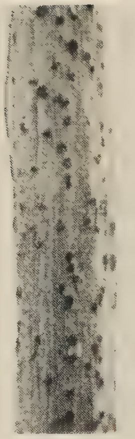

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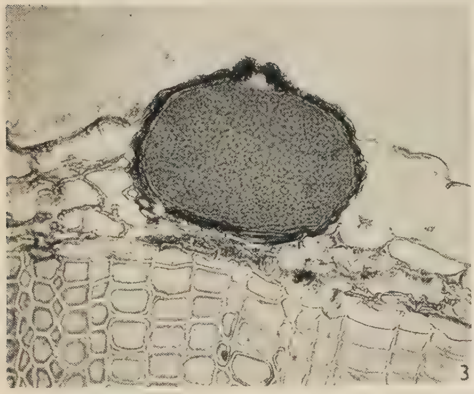

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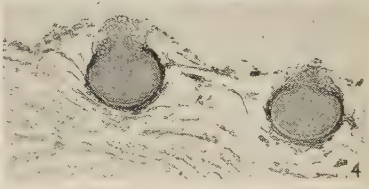

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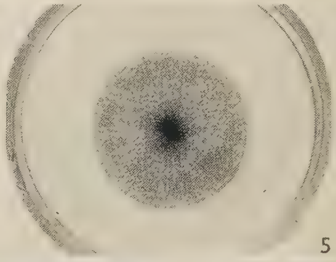

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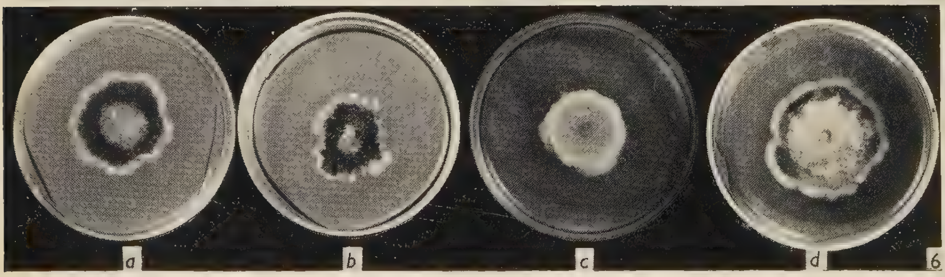

6

LEPIK, E. (1931). Phytopathological Notes, 2–8. *Mitt. Phytopath. Versuchsstat. Univ. Tartu* (Esthonia), **7**. (Abstr. in *Rev. appl. Mycol.* **11**, 24–25.)

MARCHAL, E. & VERPLANCKE, G. (1926). Champignons parasites nouveaux pour la flore Belge observés de 1919 à 1925. *Bull. Soc. Bot. Belg.* **59** (N.S. **9**). (Abstr. in *Rev. appl. Mycol.* **6**, 258.)

MARCHAL, P. & FOËX, E. (1927). Rapport phytopathologique pour les années 1926–7. *Ann. Epiphyt.* **13**, 383–454. (Abstr. in *Rev. appl. Mycol.* **8**, 150–151.)

MILLIKAN, C. R. (1944). Phoma stem disease of flax. *J. Aust. Inst. agric. Sci.* **10**, 129–130.

MOORE, W. C. (1948). Diseases of crop plants, 1943–46. *Bull. Minist. Agric., Lond.*, no. 139, 76–77.

MUSKETT, A. E. & COLHOUN, J. (1947). *The Diseases of the Flax Plant.* Belfast.

NAOUMOFF, N. A. (1926). Novelties of the local mycoflora. *Mycology, Leningrad*, I. (Abstr. in *Rev. appl. Mycol.* **5**, 610–611.)

NAOUMOVA, N. A. (1932). Stem spot of flax caused by *Ascochyta linicola* Naoumoff & Vassilievski. *Bull. Plant Protect., Leningrad*, **5**, 1, 141–160. (Abstr. in *Rev. appl. Mycol.* **11**, 647.)

NAVRATILOVA, H. N. (1949). Usychani Lnu. *Ochr. Rost.* **22**, 3–4, 121–129.

PASSERINI (1890). Diagn. F. N. IV, 81. (Saccardo, *Syll.* **10**, 171, 1892.)

PETHYBRIDGE, G. H., LAFFERTY, H. A. & RHYNEHART, J. G. (1921). Investigations on flax diseases (Second Report). *J. Dep. Agric. Ire.* **21**, 167–187.

ROST, H. (1938). Untersuchungen über einige Krankheiten des Leins in Deutschland. *Angew. Bot.* **20**, 412–430.

ROTHERS, B. V. (1927). A note on two new fungi parasitic on flax. *La défense des Plantes, Leningr.* **4**, 535. (Abstr. in *Rev. appl. Mycol.* **7**, 446.)

RUDIGER, W. (1948). Untersuchungen über die Pustelkrankheit des Leins (*Phoma lini*). *Beitr. Agrarwiss.* **2**, 56–60. (Abstr. in *Biol. Abstr.* **24**, 2034, 1950.)

SASS, J. E. (1929). The cytological basis for homothallism and heterothallism in the Agaricaceae. *Amer. J. Bot.* **16**, 663–701.

UNAMUNO, L. M. (1930). New contributions to the study of the mycological flora of the Concejo de Llanes (Asturias). *Bol. Soc. esp. Hist. nat.* **30**, 179–187. (Abstr. in *Rev. appl. Mycol.* **9**, 611.)

VAN POETEREN, N. (1929). Verslag over de werksaameden van den Plantenziektenkundigen Dienst in het jaar 1927. Versl. en Meded. *Planten ziektenkundigen Dienst te Wageningen*, 55. (Abstr. in *Rev. appl. Mycol.* **8**, 547–548.)

WESTENDORP (1854). *Les Cryptogames classés d'après leur stations naturelles.* Gand.

EXPLANATION OF PLATE 4

Fig. 1. Pycnidia of *Ascochyta linicola* on cotyledon of an infected seedling. × 50.

Fig. 2. Part of the diseased base of a mature flax plant suffering from foot rot. × 7.

Fig. 3. Transverse section through base of flax plant suffering from foot rot. Cortical tissues are completely disorganized. × 185.

Fig. 4. Transverse section through lesion caused by isolate A on tomato fruit. × 50.

Fig. 5. Malt-agar culture of non-pathogenic *Phoma* isolated from flax seed, 7 days old.

Fig. 6. *Ascochyta linicola.* (*a*) Malt agar culture of strain A, 7 days old. (*b*) Malt agar culture of strain B, 7 days old. (*c*) Malt agar culture of strain C, 7 days old. (*d*) Malt agar culture of strain C, 7 days in incubator at 26° C., 7 days at room temperature (15° C.), and in diffused daylight.

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THE GENUS *USTILAGOPSIS* SPEG.

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The genus *Ustilagopsis* Speg. is shown unnecessary. The type species *U. deliquescens* represents the sphacelial state of *Claviceps paspali* Stev. & Hall. The probable identity of two other species of *Ustilagopsis* is discussed.

The genus *Ustilagopsis* was proposed by Spegazzini in 1880 for *U. deliquescens*. Spegazzini expressed doubt as to the proper systematic position of the genus which he placed among the Ustilaginales (Spegazzini, 1880). Ciferri (1938) listed *Ustilagopsis* among the Ustilaginales, but indicated that he was uncertain about it, as did Ainsworth and Bisby (1950). A review of the available information on the species of *Ustilagopsis* described by Spegazzini will make the status of this genus clear.

Ustilagopsis deliquescens Speg.

This species was described in 1880 as parasitic on the young ovaries of *Paspalum* in the Argentine. It caused a copious viscid exudate in which were embedded biguttulate, hyaline, elliptic-elongate spores measuring 10–15 × 5–6μ. Spegazzini first regarded the species as belonging to the Ustilaginales, but later ascribed it to the Saccharomycetes (Spegazzini, 1909). Hauman-Merck (1914) supported this latter belief. Later, Hauman and Parodi (1921) recognized the disease of *Paspalum* caused by *Ustilagopsis deliquescens* as an ergot disease. They transferred the species to *Claviceps* and at the same time remarked that *C. paspali* was probably the same as *C. deliquescens*. They did not see the ascal state of their fungus but made the transfer to *Claviceps* on the basis of an undoubted sphacelial state. Marchionatto (1930) accepted the name *C. paspali* for *Ustilagopsis deliquescens*, though at that time he had seen the fungus only in its imperfect states. Later he studied the fungus in its perfect state and confirmed that *Ustilagopsis* was based on the imperfect state of *Claviceps paspali* (Marchionatto, 1937).

Ustilagopsis compactiuscula Speg.

This species, parasitic on the ovaries of *Vilfa*, has hyaline, elliptic spores, 6–12 × 2·5–3·5μ (Spegazzini, 1883). *Sclerotium compactiusculum* Speg. on *Panicum* was described in 1922 and was said to be the sterile state of *Ustilagopsis compactiuscula* (Spegazzini, 1922). In the Herbarium, Royal Botanic Gardens, Kew, are two collections of *U. compactiuscula* which I have been able to examine. These exsiccati are: (*a*) B. Balansa: Pl. du Paraguay, 1878–84; no. 2754, on *Panicum*; and (*b*) C. Roumeguère: Fungi selecti exsiccati, no. 4112, on *Vilfa*. Remnants of a conidial state are present as well as sclerotia. In all characters, these specimens conform to the description and illustrations of *Claviceps lutea* given by Möller (1901).

I have not been able to see authentic material of *C. lutea*. By courtesy of Dr W. W. Diehl, two specimens considered to belong to that species have been made available to me from the Mycological Collection of the United States Department of Agriculture. The hosts are *Panicum millegrana* and *Panicum* sp., and the fungi conform to Möller's description and figures of *Claviceps lutea* in its imperfect state.

All of the specimens mentioned above have come from the same geographical area and thus there is a reasonable basis for considering *Ustilagopsis compactiuscula* and *Sclerotium compactiusculum* to be names for imperfect states of *Claviceps lutea*.

Ustilagopsis bertoniensis Speg.

This species was described by Spegazzini (1919) from *Panicum*. No other mention of the fungus has been found. From Spegazzini's description one might infer that he was dealing with a species of *Cerebella*. I have not seen any specimens.

DISCUSSION

It has been clearly demonstrated by South American workers that *Ustilagopsis deliquescens* Speg. is the same fungus as *Claviceps paspali* Stevens & Hall. The valid name for the organism is *C. paspali* which was the first name applied to the perfect state of the ergot fungus on *Paspalum* (Stevens & Hall, 1910). *Ustilagopsis deliquescens* is not a valid species, and therefore the genus *Ustilagopsis* cannot be maintained.

Spegazzini, in two instances, appears to have used the name *Ustilagopsis* for fungi which in their imperfect states could be included in the form genus *Sphacelia*. *Ustilagopsis deliquescens* and *U. compactiuscula* represent imperfect states of *Claviceps paspali* and *C. lutea*, respectively.

Spegazzini's description of *Ustilagopsis bertoniensis* makes it clear that he had a fungus which was not a sphacelial state of *Claviceps*. He has suggested in some notes that accompany the description of his species that it has many of the characters of the genus *Poikilosporium* (a synonym of *Thecaphora*). As already suggested, one might infer that *Ustilagopsis bertoniensis* is a species of *Cerebella*, a genus which has on occasion been confused with *Thecaphora* (Saccardo, 1891), and which is now known to be commonly associated, in a saprophytic role, with the sphacelial state of *Claviceps* (Langdon, 1942).

REFERENCES

AINSWORTH, G. C. & BISBY, G. R. (1950). *A Dictionary of the Fungi*, 3rd ed. Kew.

CIFERRI, R. (1938). *Flora Italica Cryptogama*, **1**, Fasc. 17, p. 52.

HAUMAN-MERCK, L. (1914). Les parasites végétaux des plantes cultivées en Argentine. *Ann. Mus. Nac. Nat. Hist.* **26**, 163–225.

HAUMAN, L. & PARODI, L. R. (1921). Los parasitos vegetales de las plantas cultivades en la Republica Argentina. *Rev. Fac. Agron. B. Aires*, **3**, 227–274.

LANGDON, R. F. (1942). The genus *Cerebella* Cesati. Its biologic status and use. *Phytopathology*, **32**, 613–617.

MARCHIONATTO, J. B. (1930). Sobre algunos hongos parasitos de las Gramineas toxicos para el ganado. *Bol. Min. Agric. Argent.* **29**, 457–462.

Marchionatto, J. B. (1937). Nota Biologica sobre el '*Claviceps paspali*'. *Rev. Argent. Agron.* **4**, 147–152.

Möller, A. (1901). *Phycomyceten und Ascomyceten, Untersuchungen aus Brasilien*, pp. 304–305, Jena.

Saccardo, P. A. (1891). *Sylloge Fungorum*, **9**, 290.

Spegazzini, C. (1880). *Fungi Argent.* pug. II, n. 27.

Spegazzini, C. (1883). *Fungi Guaran.* pug. I, n. 97.

Spegazzini, C. (1909). Mycetes Argentinenses. *Anal. Mus. Nac. B. Aires*, **19**, 257–458.

Spegazzini, C. (1919). Reliquiae Mycologicae Tropicae. *Bol. Acad. Nac. Cienc. Cordoba*, **23**, 365–609.

Spegazzini, C. (1922). *Fungi Parag.* n. 266.

Stevens, F. L. & Hall, J. G. (1910). Three interesting species of *Claviceps*. *Bot. Gaz.* **50**, 460–463.

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CHEESMAN AND PETHYBRIDGE BEQUESTS

The terms approved by the Council for the administration of these Bequests provide for financial help by the allocation annually of grants to enable one or more students of mycology to attend the Autumn Foray or Plant Pathology Field Meeting, who would otherwise be unable to do so. Applications from students or recommendations from Heads of Departments or members of the Society should reach the Secretary, or the Secretary of the Plant Pathology Committee, not later than 1 May each year.

REVIEWS

Précis de Mycologie. Mycologie générale, mycologie humaine et animale, techniques. By M. Langeron. 2nd edition revised and enlarged by R. Vanbreuseghem. (Masson et Cie, Paris, 1952.) ix + 703 pp., 461 text-figures. Price: Fr. 4800 (bound: Fr. 5400).

The publication of Langeron's *Précis de Mycologie* in 1945 was an important mycological event. The first printing was soon exhausted, and the appearance of a second and much enlarged edition will be welcomed by mycologists both for itself and as a fitting memorial to the late Dr Langeron's mycological scholarship and industry. The attractive and strong covers of the new *Précis* enclose a mycological trilogy which provide a severe test of a reviewer's versatility, but any ill-considered judgements are unlikely to affect the wide circulation that this notable work will receive.

The first part is Langeron's very individual and now familiar presentation of general mycology. After a brief systematic outline (which might perhaps have been more logically placed at the end of the section, if not at the end of the volume, as in the first edition) there follow chapters or series of chapters on morphology, spore discharge and dispersal, the principles of mycology, and sexuality, and if the treatment is in many ways unsuited as an undergraduate text it provides a stimulating antidote to the traditional taxonomic approach. A jaded examiner will find many fresh ideas for testing the knowledge of the 'question-spotter' while the student will find much to enliven the most hackneyed essay topic. The generous selection of more than a hundred illustrations from Buller's studies on spore discharge and dispersal and on sex in agarics is particularly welcome now that Buller's *Researches* are no longer obtainable.

The second, and very useful, part on technique is the mycological supplement to Langeron's *Précis de Microscopie*, 1949, while the final section is a new treatment of medical mycology by Vanbreuseghem, the student and friend of Langeron who has edited the new edition. This good straightforward account of the principal mycoses of man and animals merits separate notice as a major contribution to the growing literature of medical mycology. Here one can only wonder what the medical reader will make of the mycological section and the pure mycologist of the medical mycology but perhaps the juxtaposition of these rather diverse elements will encourage the specialist to wander from his own narrow path. G. C. AINSWORTH

Index of Fungi 1929, pp. 40, 1952, price 10*s.*; *Index of Fungi 1930*, pp. 123, 1952, price 25*s.*; *Index of Fungi 1936–1939*, pp. 117, 1950, price 30*s.* By F. Petrak. (Commonwealth Mycological Institute, Kew, Surrey.)

Since 1940, the Commonwealth Mycological Institute has been publishing the *Index of Fungi* as half-yearly lists of new species and new varieties, new combinations and new names together with host indexes. Similar lists for 1920–35 were published by Franz Petrak in *Just's Botanischer Jahresbericht* during 1930–44. Since the war, at the instigation of the Commonwealth Mycological Institute, Dr Petrak compiled a final instalment which has been published as *Index of Fungi 1936–9*, whilst the Institute acquired the stock of Petrak's 1932–5 list and began to re-issue the others, the stocks of which had been destroyed, in the *Index of Fungi* series. Cumulative indexes to the first ten years of the *Index of Fungi* and to the series of Petrak lists are promised, and so before long mycologists should have a virtually complete index to species and names published since 1920. This project, which is clearly a notable contribution to the 'organization of the study of systematic mycology', deserves the support of mycologists everywhere. G. C. A.

The Microbiological Assay of the Vitamin B-complex and Amino-Acids. By E. C. Barton-Wright. (London: Pitman, 1952.) x+179 pp., 25 text-figures. Price 18*s.*

One of the most valuable practical applications of the recent advances in our knowledge of the nutrition of micro-organisms has been the rapid development of methods of microbiological assay of vitamins and amino-acids. These methods are sensitive, rapid and, if proper precautions are observed, of a high degree of accuracy. They have many advantages over the available methods of chemical estimation and the older technique of estimation through cumbrous animal feeding experiments. The rapid development of this branch of microbiology has, however, produced a formidable list of suggested organisms for use in assays of various substances. Thus the chemist or even the trained microbiologist wishing to use the technique of microbiological assay is faced with a bewildering array of suggested methods and test organisms. Dr Barton-Wright has rendered a conspicuous service in selecting and describing proved methods for the estimation of the vitamins of the B-complex and the more important amino-acids. His book opens with a brief survey of the nutritional facts on which the whole idea of microbiological assay is based. In the interests of brevity it is inevitable that such a survey, while adequate as a basis for the understanding of the assay techniques, tends to give rather an unbalanced impression of the vast amount of recent work on the nutrition of micro-organisms. The inclusion of more references to recent reviews of this subject would have corrected this impression without lengthening the introductory chapter. A critical general description of assay methods and of some of the difficulties encountered follows. The bulk of the book is devoted to detailed accounts of the best available methods for the assay of particular substances. This part of the book is admirable in its clarity and in its attention to detail and to the probable causes of errors.

It may well prove in the light of further experience that the author has been a little too hasty in discarding some of the published methods. One can visualize, too, occasions when the use of 10 ml. samples as recommended would be difficult and there is no valid reason why smaller samples should not give satisfactory results when proper precautions are taken.

Nevertheless, Dr Barton-Wright is to be congratulated in the production of such a concise guide, and his book will be of great use to all those investigators in varied fields who require an accurate and relatively simple means of estimating a particular vitamin or amino-acid.

L. E. HAWKER

Phytopathologie des Pays Chauds, Tome 1. By L. Roger. (*Encyclopédie Mycologique,* Tome 17, Paris, Paul Lechevalier. 2 Août 1951.) 1126 pp., 153 text-figures. Price: Fr. 9000.

Dr Roger's monumental work of which volumes 2 and 3 are to appear later, has been written to replace Delacroix and Maublanc's *Maladies des Plantes Cultivées,* now out of date and out of print. Like its predecessor, however, it should, and almost certainly will, have a much wider circulation than in French Colonial Territories for which it is primarily intended. Indeed, this book will find its place as a valuable addition to the reference libraries of plant pathologists working in the tropics generally.

The author states that the plan of the work is based on a course of lectures of which he had charge between 1934 and 1938 at the 'Institut National d'Agronomie de la France d'Outremer'. But throughout the book one feels that this is no mere compilation, but largely the outcome of meticulous and often brilliant observations on material submitted to him for study, or from first-hand information obtained in Indo-China or French Equatorial Africa.

The work is divided into three main parts: the first consists of nine chapters and covers an historical account of plant pathology, a discussion on parasitic and non-parasitic diseases, susceptibility, resistance and immunity, symptomatology and morbid anatomy, and the influence of environmental factors on the development of diseases. Part 1 concludes with a comprehensive account on control measures studied under the following headings: preventive and curative measures, biological control (hyperparasites and antibiotics), phytosanitary legislation in force in French territories; no mention is made of systemic fungicides. Part 1 would have gained with more illustrations, particularly as regards symptomatology and morbid anatomy. Similarly, the chapter on environmental factors offered scope for more diagrams, but we are informed that Dr Roger's collection of photographs which were intended for publication were unfortunately destroyed during the last war.

The second part, deals with a descriptive account of parasitic diseases classified as to their cause. Fungi are considered first, followed by algae, bacteria, flowering parasites and viruses. The third part reviews phytopathological problems of the tropics classified under crop plants.

In Part 2, volume 1 takes us from generalities on fungi to Basidiomycetes in 598 pages with few but good illustrations, all by the author. One cannot but regret that the physiology of parasitism is not discussed at greater length in the general account on fungi. The phylogenetic chart facing page 544 is informative and provides a useful guide to the classification of fungi. In the description of specific diseases comprehensive notes are given on etiology, symptoms, economic importance and control measures. Geographical distribution of the pathogens is also indicated, but they are often unfortunately incomplete (e.g. *Exobasidium vexans*, *Puccinia polysora*, *Ustilago scitamineae*, etc.); it seems a pity that reference to the distribution maps of the Commonwealth Mycological Institute has not been given where available. In several instances the appellation of fungi does not follow the names generally adopted in Britain, thus *Puccinia maydis* Bereng. is preferred to *P. sorghi* Schw. References should have formed an essential part in a work of this magnitude. Indeed Dr Rogers tells us in his introduction that he hopes to publish a bibliography in a separate volume, but there is no doubt that in its present form the inclusion of selected references at convenient places would have greatly enhanced the value of this book.

Volumes 2 and 3 are now eagerly awaited. Dr Roger has earned the gratitude of plant pathologists throughout the tropics for giving them an admirable treatise on the problems which they have to face. Similarly, the publishers are to be congratulated on yet another valuable addition to the *Encyclopédie Mycologique*. P. O. WIEHE

Plant Pathology. Published quarterly for the Ministry of Agriculture and Fisheries Plant Pathology Laboratory, Harpenden, Herts. Vol. 1, No. 1, March, 1952. London: H.M. Stationery Office. Subscription: 16*s*. 6*d*. per year.

Mr W. C. Moore's prefatory note to this new journal states: 'The *Science of Plant Pathology* is concerned with all pathological conditions in plants and plant produce, whatever causal agent is involved. It therefore provides common ground for the mycologist, entomologist, virus worker, helminthologist, bacteriologist, nutrition or soil chemist, meteorologist, and plant physiologist, each specializing along his own lines, but collaborating closely with workers in cognate branches. The periodical *Plant Pathology*, like the science from which it takes its name, will be wide in its scope. It will contain original contributions on plant diseases caused by fungi, bacteria, viruses and eelworms; on plant pests, including those of stored products; on damage by rodents and birds; and on nutritional and physiological disorders. It is intended primarily for the prompt publication of information on the incidence, distribution, recognition and control of plant diseases and pests in Britain. It will record survey work, including estimates of crop losses, and contain much matter of topical interest on preliminary experiments and their provisional interpretation, on forecasts, and on precautionary measures.'

This catholic approach is exemplified in the first number—a pleasant but slim issue of 34 pages illustrated by a few text-figures and 4 plates—which contains material dealing with potato-haulm killing, aphid identification, import and export regulations, rabbit repellents, choke disease, seed disinfection, tortrix injury, the International Plant Protection Convention, cereal diseases and the weather of 1951.

Clearly, in all this there is ample scope for difference of opinion. For example, does it represent a progressive and rational synthesis of disparate but logically related fields of study or a reactionary and artificial lumping of trends and specialisms which are developing rationally and logically as autonomous disciplines? Further, the contributions to this journal, although rather slight, could have found homes in existing periodicals and in these days, when time, money, and shelf space are urgently limiting factors, mycologists, helminthologists, nutrition chemists, meteorologists, etc., etc., 'each specializing along his own lines' may doubt the necessity of a new omnibus journal. They may also wonder whether accumulating scripts and quarterly issues may not soon stifle any optimistic ideas regarding 'prompt publication', etc.

Whilst one appreciates the recognition of the importance of plant pathology shown by the Ministry of Agriculture and Fisheries in the establishment of this journal one just cannot help wondering whether the urgent need to-day is not the reorganization of the entire system of scientific publication on a more rational basis and not the *ad hoc* foundation of still more new journals. WILLIAM B. BRIERLEY

Sugar-Beet Disease in Ireland. By ROBERT McKAY. (Dublin: At the Sign of the Three Candles, 1952.) Pp. x + 77, and 37 plates. Price 21*s.*

Dr McKay had two objects in preparing this book: (1) to record the diseases of sugar beet known to occur in Ireland, and (2) to summarize existing knowledge on them for those concerned with beet growing. It is agreeably surprising to find such modest aims resulting in a book that is a joy to handle; good paper, large print, generous margins, and excellently chosen and reproduced photographs, all combine to make a balanced production of unusually high quality. The 38 half-tone photographs are so good that, although the 10 colour plates are better than most of their kind, one reader still wondered whether colour adds enough to justify its cost.

The text is a straightforward account of the diseases, their symptoms, etiology, the conditions that affect their incidence and, when known, the ways in which they can be controlled. There is a glossary in which technical words are defined simply and clearly; the inclusion of such words as chlorophyll and parasite indicates the type of reader to whom the text is addressed. The book fulfils its purpose well, for although there are a few ambiguous and odd phrases (what is 'pathological literature'?), the writing is generally clear and free from jargon. Some references are given after the account of each disease, but it is difficult to see what purpose these serve and the selection sometimes seems bizarre. For example, considering the aims of the book and the large amount of recent literature on beet yellows in English, it is inexplicable that three of six references to this disease are to papers published in Dutch before 1936.

At present costs of publication, the price is no doubt reasonable for such a quality product: it is to be hoped that it is not so high as to prevent the book being bought by those to whom it would be of greatest value. F. C. BAWDEN

Mushroom Research Station: Reports, 1946–8, 1949, 1950, 1951. (Mushroom Research Association Limited, Yaxley, Peterborough, 1949–52.) Price: 1946–8, 10*s.*; 1949, 5*s.*; 1950, 5*s.*; 1951, 5*s.*

The shortage since the war of good quality manure for composting faced the mushroom industry with the difficult problem of finding a satisfactory substitute if adequate production was to be maintained. A group of mushroom growers took the initiative, and under the Chairmanship of Major C. P. Whitaker, and later of Mr Fred. C. Atkins, the Mushroom Research Station at Yaxley was started with Dr R. L. Edwards as Director. Beginning as a private enterprise, the project soon received a grant from the Ministry of Agriculture and Fisheries. The many interesting subjects described include: chemical changes in compost, both during the composting process and in cropping; the development of the M.R.A. synthetic compost; the problem of what constitutes a good casing soil; mushroom diseases such as *Mycogone perniciosa*, and mushroom-bed invaders such as *Pseudobalsamia microspora*. The publication of these *Reports* of work done at the Station will be welcomed, not only by growers, but by most other kinds of mycologist.

P. H. G.

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A. A. PEARSON: *Cooke's illustrations of British Fungi* (*Annotations by L. Quélet, R. Maire & C. Rea*). *Ex* Vol. 20, Pt. 1. 1935. Price net, 2*s.* 6*d.* Postage, 3*d.*

T. PETCH: *British Hypocreales*. *Ex* Vol. 21, Pts. 3 & 4. 1938. Price net, 2*s.* Postage, 3*d.*

A. A. PEARSON & R. W. G. DENNIS: *Revised list of British Agarics and Boleti*. *Ex* Vol. 31, Pts. 3 & 4. 1948. Price net, 5*s.* Postage, 3*d.*

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INSTRUCTIONS TO AUTHORS

Contributors are asked to be clear and concise, and to use a recent issue of the *Transactions* as a guide to the arrangement of headings and subheadings, explanations of plates and figures, references to the literature, and other details. Each paper should start with a short summary.

The standards adopted in the *Transactions* are those outlined in the Royal Society's pamphlet, *General Notes on the Preparation of Scientific Papers* (1950, Cambridge University Press, 200 Euston Road, London N.W. 1, price 2*s*. 6*d*.). An exception is that in the *Transactions* citations of references to literature, although based on the Harvard system, include the full titles of the papers and complete page numbers. Titles of journals are abbreviated in accordance with *A World List of Scientific Periodicals*, 1952.

The scientific names of genera and species are printed in italics and should be underlined in the typescript. The title of the paper, headings, and subheadings may be in capitals, but should not be underlined.

The attention of authors proposing new taxonomic groups is drawn to the need to give an adequate description and figure, and to designate the types as required by the *International Code of Botanical Nomenclature*. The description of a new species should be accompanied by a figure, and whenever possible the type specimen should be deposited in one of the national herbaria.

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